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At a Countil meeting, held 1944 December 8, the following were elected Fellows of the Society:—

Frederick Ronald Curtis, B.Sc., 6 Hartside Gardens, Jesmond, Newcastle-upon-Tyne, 2;

Norman John Harris, 7 Humber Road, Blackheath, London, S.E. 3; and

Russell F. Moore, 7 Randolph Place N.W., Washington 1, D.C., U.S.A.

The following candidates were proposed for election as Fellows of the Society, the names of proposers from personal knowledge being appended:—

John Maurice Barnett, Lieut. R.E., c/o Lloyds Bank Ltd., Woking, Surrey (proposed by H. Spencer Jones);

Cecil John Sidney Bromfield, Dingle Combe, Potters Cross, Iver Heath, Buckinghamshire (proposed by V. Orloff);

George Edward Raven Deacon, D.Sc., F.R.S., Sea Lanes, Seamill, Ayrshire (proposed by D. H. Sadler);

Frederick George Humphrey Elphick, 11A Broadway, Southall, Middlesex (proposed by V. Orloff);

Cyril King, 12 Moorside South, Fenham, Newcastle-upon-Tyne, 4 (proposed by F. C. Molesworth);

Donald William Millar, B.Sc., 7 Bournville Road, Catford, London, S.E. 6 (proposed by F. J. Hargreaves);

William Daniel Morgan, 1764 St. Anthony Avenue, St. Paul, Minn., U.S.A. (proposed by F. R. Moulton);

William Humphrey Robertson, B.Sc., Sydney Observatory, New South Wales, Australia (proposed by H. Wood);

Frederico Rutllant, Trinity College, Cambridge (proposed by H. A. Brück); and

Carl Leo Stearns, Ph.D., Van Vleck Observatory, Wesleyan University, Middletown, Conn., U.S.A. (proposed by F. Slocum).

RE-OBSERVATION OF THE MAGNITUDES OF THE SOUTHERN COMPARISON STARS FOR EROS

R. H. Stoy and A. Menzies

Communicated by H.M. Astronomer)

(Received 1944 October 11)

Summary

Table II gives the magnitudes on the Cape system of 247 of the stars which were used as comparisons for Eros during its 1931 opposition, and of 86 brighter stars in the same region of the sky. A comparison of these magnitudes with those determined at Yerkes and Mount Wilson shows that the Yerkes magnitudes need a large systematic correction depending on declination. The Mount Wilson magnitudes are also suspect owing to large plate corrections which had to be evaluated by means of the Yerkes magnitudes. It was therefore not possible to make a satisfactory comparison between the Cape and international magnitude systems.

Introduction.—It will be recalled that in a former paper * the attempt to link the Cape magnitude system with the international system was based on the observation of certain members of the Hyades, Præsepe and Pleiades clusters. This attempt was not altogether successful owing to the absence for these stars of well-determined magnitudes on the International Scale. It therefore appeared desirable to reobserve some of the southern comparison stars of Eros, as photographic and photovisual magnitudes for about 300 of these stars had been determined at Mount Wilson† by direct comparison with the Polar Sequence. Moreover, over a hundred of these stars had been similarly observed at Yerkes.‡

Unfortunately the need for this work did not become apparent until the middle of May when the best time of the year for observing these Eros stars had already passed. To avoid a year's delay a compromise programme was drawn up and, though partly frustrated by poor weather, carried out. The internal consistency of the derived magnitudes proved to be satisfactory and, as comparisons with the Mount Wilson and Yerkes magnitudes show that little is to be gained by further observation, the results are presented here.

Observational Material.—The observational material is summarised in Table I. The instrumental equipment with which it was obtained and the procedure followed is the same as that described in the previous paper. Twelve overlapping regions were observed, their centres roughly corresponding with twelve of the regions observed at Mount Wilson. The first three columns of Table I give the number and centres of these regions. The fourth and fifth columns give the dates on which the grating plates (exposure 30 mins.) were obtained and their zenith distance at the time of mid exposure. The sixth and seventh columns give similar data for the plates comparing these regions with one of the standard E Regions at -45° , the particular E Region used being indicated in the eighth column. Each of these comparison plates received four three-minute exposures, the first of them on the E region, the second and third on the Eros region being compared with it and the last one on the E region, the exposures being so timed that the two regions being compared were at equal zenith distance. In order to complete the observing programme

* *M.N.*, 103, 288, 1943.

† *Ap. J.*, 72, 311, 1930.

‡ *A.N.*, 239, 289, 1930.

in 1943, this latter condition had to be relaxed in the case of the comparison plates for regions 12 and 15, but in neither case did the difference in zenith distance exceed 6° . Where possible only the best nights were used for obtaining the comparison plates. All the plates were taken by Stoy.

TABLE I
The Observational Material

Region	R.A.	Dec.	Grating Plates		Comparison Plates		
	(1930.0)		Date	Z.D.	Date	Z.D.	E
	h m	° '	1943	°	1943	°	
1	10 24	- 2 00	May 26	32	June 5	37	6
2	10 22	- 5 00	June 3	31	June 21	35	4
3	10 18	- 8 00	June 21	48	June 20	34	6
4	10 13	-11 00	May 26	30	June 23	37	4
5	10 09	-14 00	June 3	32	June 5	24	4
6	10 05	-17 00	June 22	40	June 21	38	4
7	9 57	-19 00	June 25	43	June 23	42	4
8	9 52	-22 00	June 22	49	June 25	32	6
12	9 57	-25 00	July 6	44	July 5	46	7
13	10 10	-24 00	July 5	56	July 13	45	7
14	10 20	-23 00	June 3	34	July 5	44	7
15	10 30	-22 00	May 26	28	July 6	44	7

The plates were measured with the Schilt photometer by Menzies and Stoy. No rigid rule was observed, but in general the photographic plates were measured by Menzies, the photovisual plates by Stoy. An area of 7° by 7° —nearly twice that employed for the zone work—was measured on each plate. This larger area was used partly to increase the number of observations of each star and partly to provide the material for an investigation of the distance correction.

After the differential extinction corrections had been applied, the measures of the comparison plates were reduced to the P_g, P_v system* of the Standard E Regions and the resulting magnitudes formed into a provisional catalogue. This catalogue was used to reduce the measures of the grating plates. As in the zone work, the gratings were used only to extrapolate the range of magnitudes found from the comparison plates. Each plate was reduced with the value of the grating constant deduced from stars of known magnitude on that plate. The range in the value of the derived grating constants was small, as might be expected from the fact that the plates were taken and measured under more or less uniform conditions. No attempt was made to modify the value of the grating constant for the colour of the individual stars.

When the reduction of the grating plates had been completed, the mean of all the determinations of magnitude, both on the grating and on the comparison plates, was taken and regarded as the star's magnitude on the P_g', P_v' system. These magnitudes reduced to the provisional IP_g, IP_v system by means of the formulæ

$$IP_g = P_g' - 0.11P_v + 0.880$$

$$IP_v = P_v' + 0.14C.I._{\text{Cape}}$$

are given in Table II, the number of determinations on which each magnitude depends being shown in column six. The magnitudes determined from the central and from the side images on a grating plate were regarded as two separate determinations. The first part of Table II refers to the "Kopff Stars"—the Eros comparison stars proper—while the second part refers partly to the "Bright Extra Stars" which were measured by the

* The notation used is that defined in the previous paper. P_g, P_v and P_g', P_v' denote the observed system of magnitudes; IP_g, IP_v the standard system to which these observed systems are reduced. The term "Cape magnitudes", which is sometimes used in this paper, refers to the IP_g, IP_v system. The use of IP_g and IP_v to denote the Cape system was over-optimistic.

TABLE II

(a) *The Kopff Stars*

Kopff	IPg	IPv	C.I.	Sp.	No. of Obs.	Mt. Wilson	Yerkes
439	8.01	8.21	-0.20	B9	3, 2	- 1	-15
440	10.69	9.90	+0.79	Ko	1, 1	+15	+ 9
444	9.61	9.62	-0.01	A7	2, 1	- 8	+ 9
445	9.93	9.12	+0.81	Ko	2, 1	+20	+23
446	9.14	8.79	+0.35	F8	3, 2	- 5	- 3
447	8.78	7.52	+1.26	Ko	3, 3	-11	-16
451	9.43	8.60	+0.83	Ko	2, 2	+ 4	+ 9
452	9.99	9.18	+0.81	Ko	4, 2	+12	+17
453	9.99	8.94	+1.05	G5	4, 2	+19	+21
454	9.13	8.05	+1.08	Ko	3, 2	- 9	+ 2
455	10.42	9.70	+0.72		4, 3	+46	+33
456	8.92	8.48	+0.44	Go	6, 4	+ 7	+ 8
457	10.60	9.37	+1.23	K5	2, 2	+33	+ 9
458	10.62	9.31	+1.31	Mo	2, 2	+17	+ 9
459	9.88	8.90	+0.98	Ko	4, 4	+ 1	+15
460	9.62	9.37	+0.25	F5	6, 3	+ 6	+17
461	10.09	9.21	+0.88	Ko	3, 2	- 3	+ 9
462	9.11	8.33	+0.78	Ko	5, 4	- 4	- 3
463	10.26	8.97	+1.29	K2	4, 5	+21	+16
464	9.26	8.43	+0.83	Ko	5, 4	- 5	+ 2
465	10.22	9.05	+1.17	K	4, 2	+10	+22
466	10.37	8.94	+1.43	K5	3, 3	+ 6	+21
467	9.78	9.50	+0.28	F8	5, 3	+23	+ 7
468	10.37	9.60	+0.77	G5	3, 2	+39	+23
469	9.79	8.66	+1.13	K2	2, 2	-22	+ 5
470	9.68	8.24	+1.44	K2	4, 4	- 5	+ 5
471	9.08	9.12	-0.04	B8	5, 2	-13	+30
473	8.89	8.72	+0.17	A5	6, 4	-18	+ 1
474	8.62	8.34	+0.28	Fo	6, 4	-16	+10
475	8.79	8.94	-0.15	Ao	3, 1	- 5	+ 6
476	10.05	9.15	+0.90	G5	4, 2	-12	+13
477	9.80	9.33	+0.47	Ko	2, 1	+ 1	+13
478	10.12	9.72	+0.40	Go	3, 2	-10	+18
480	9.27	8.97	+0.30	F5	4, 2	- 3	+10
481	8.82	7.96	+0.86	G5	5, 5	-13	+ 1
482	10.07	9.85	+0.22	A2	4, 2	+ 3	+ 8
483	9.62	9.18	+0.44	Go	6, 3	+ 6	+11
484	9.61	9.17	+0.44	G5	4, 2	0	+ 5
485	9.80	8.42	+1.38	K5	2, 2	- 7	+ 1
486	9.75	8.28	+1.47	K5	4, 4	-10	+ 7
487	9.92	9.41	+0.51	G5	5, 3	+ 3	+ 8
488	9.81	8.85	+0.96	G5	6, 5	+ 8	+ 5
489	9.27	7.98	+1.29	K2	6, 6	- 5	+ 8
490	9.26	8.65	+0.61	G5	7, 6	- 9	- 6
491	8.94	8.47	+0.47	Go	6, 4	-15	+ 4
492	10.20	9.81	+0.39	F5	3, 2	+13	+17
493	10.30	9.83	+0.47	G	4, 2	+ 3	+17
494	10.10	9.11	+0.99	Ko	6, 3	+15	+ 6
495	9.97	9.11	+0.86	G5	4, 2	- 2	+ 6
496	10.42	9.14	+1.28	K5	4, 3	+34	+ 7

TABLE II—continued

Kopff	IPg	IPv	C.I.	Sp.	No. of Obs.	Mt. Wilson		Yerkes	
497	9.03	8.07	+0.96	Ko	9, 6	-11	-14		
498	10.09	9.76	+0.33	F5	4, 2	+1	+21		
499	8.52	7.95	+0.57	Go	6, 4	+4	+9		
500	9.72	9.54	+0.18	Fo	4, 2	-12	+15		
501	9.86	9.43	+0.43	Ko	4, 2	+10	+7		
502	8.77	8.35	+0.42	F8	6, 4	-13	+1		
503	10.35	9.40	+0.95	Ko	2, 2	+26	+24		
505	10.15	9.82	+0.33	F8	4, 3	-5	-4		
506	10.38	9.86	+0.52	Go	3, 2	+2	+11		
507	9.98	9.17	+0.81	Ko	6, 3	0	+11		
508	10.15	9.27	+0.88	Ko	5, 3	+1	+3		
509	9.85	9.42	+0.43	F8	5, 3	+30	+23		
510	10.53	9.10	+1.43	K7	3, 3	+19	+8		
511	8.41	8.04	+0.37	F5	8, 6	+2	+7		
512	9.39	9.06	+0.33	Fo	6, 4	-21	+24		
514	9.65	9.27	+0.38	F8	6, 3	-8	+3		
515	9.82	9.68	+0.14	Fo	6, 3	+32	0		
516	10.72	9.88	+0.84	K5	3, 2	+22	+17		
517	9.27	9.08	+0.19	Fo	7, 3	-7	+14		
518	8.49	8.69	-0.20	Ao	8, 5	+1	-2		
519	10.13	9.77	+0.36	F2	2, 1	+29	+41		
521	9.08	8.95	+0.13	A5	8, 3	-5	-1		
522	9.30	9.13	+0.17	A2	6, 3	-4	+17	-51	-4
523	8.70	8.72	-0.02	Ao	6, 3	+15	-12		
524	10.25	9.35	+0.90	Ko	4, 3	-1	+18		
525	9.60	9.16	+0.44	F5	6, 3	-16	+4		
526	9.05	8.80	+0.25	Fo	8, 5	-22	+9		
528	9.11	7.74	+1.37	K2	6, 6	+6	-20		
529	10.22	9.12	+1.10	K5	4, 3	+26	+4		
530	10.64	9.65	+0.99	K5	3, 2	0	+2		
531	8.09	8.11	-0.02	Ao	9, 5	+4	-18	-45	-30
532	10.31	9.45	+0.86	K2	3, 2	+47	+5	+12	+7
533	10.41	9.44	+0.97	K2	3, 3	-1	+1		
534	10.39	9.39	+1.00	Ko	3, 2	+12	+13	-21	+7
535	10.45	9.45	+1.00	K2	3, 2	+8	+5		
536	9.58	9.52	+0.06	A2	6, 3	+6	+8		
537	9.77	9.46	+0.31	G5	4, 2	-1	+9		
538	10.43	9.76	+0.67	Ko	3, 2	+24	+19	+6	+36
539	9.98	9.56	+0.42	F5	5, 3	+3	+5		
540	10.32	8.96	+1.36	Mo	2, 2	+37	-2	+4	-19
541	9.52	9.10	+0.42	F8	4, 2	+6	-5	-21	-5
542	10.34	9.66	+0.68	G5	3, 2	+16	+5	-7	-10
543	10.31	9.48	+0.83	F8	4, 3	+5	+10		
544	9.71	8.83	+0.88	Ko	6, 6	0	+2		
545	10.27	9.21	+1.06	Ko	6, 3	+8	+11		
546	9.86	9.14	+0.72	Ko	3, 2	+14	+9		
547	10.82	9.67	+1.15	K5	3, 2	+19	+5		
548	8.57	7.89	+0.68	G5	9, 6	-3	-17	-40	-27
551	10.39	8.93	+1.46	M2	3, 4	+44	+8	+22	+8
553	9.69	9.24	+0.45	F8	6, 3	-10	+10		

TABLE II—*continued*

Kopff	IPg	IPv	C.I.	Sp.	No. of Obs.	Mt. Wilson		Yerkes	
554	8.18	8.29	-0.11	Ao	9, 6	-10	-15	-38	-28
555	9.54	9.14	+0.40	F8	6, 3	-5	+11	-31	-14
556	7.94	7.66	+0.28	F5	9, 8	+16	-1		
557	9.19	8.90	+0.29	Fo	7, 5	-17	+14		
558	9.85	9.38	+0.47	Go	3, 2	+3	+13		
559	10.58	9.26	+1.32	K7	3, 3	+38	+2	+40	+18
560	8.43	8.15	+0.28	Fo	6, 4	-3	-16	-34	-17
561	9.54	8.22	+1.32	K5	6, 6	-15	+12		
562	9.78	9.49	+0.29	Go	6, 2	+5	+8	-33	-5
563	10.52	9.10	+1.42	M1	2, 2	+62	+10	+45	+14
565	10.37	9.36	+1.01	K5	3, 2	+17	+1	+2	+1
566	8.95	7.95	+1.00	Ko	5, 4	+1	-9	-8	-13
567	10.02	9.23	+0.79	K2	7, 3	+8	+17		
568	8.15	7.56	+0.59	G5	6, 5	+9	-19	-43	-26
570	8.83	8.09	+0.74	G5	10, 8	-8	+14		
571	9.57	8.05	+1.52	Ma	6, 7	-16	0	-26	-12
572	9.30	9.18	+0.12	A5	8, 3	-9	+8		
574	9.22	9.13	+0.09	A2	4, 1	+5	+16	-27	+8
575	9.99	9.64	+0.35	F5	4, 2	+7	+25	-20	+35
576	10.38	9.49	+0.89	K5	3, 2	+11	+18	+15	+16
577	8.90	8.63	+0.27	Fo	5, 4	-1	-6	-16	-15
578	9.75	9.72	+0.03	Ao	6, 1	-3	+31		
579	9.83	8.46	+1.37	K2	6, 6	-16	-9	-3	-11
581	9.01	8.63	+0.38	F8	5, 4	-17	-5	-30	-15
582	9.57	8.61	+0.96	K2	8, 8	-5	+24		
583	9.45	7.80	+1.65	Ma	6, 8	-13	+3	-20	-18
585	9.28	8.87	+0.41	F8	4, 2	-3	+6	-32	-4
586	8.99	8.61	+0.38	Fo	5, 4	-41	-3	-32	-15
587	10.12	9.33	+0.79	G5	3, 3	-2	+1	-5	+3
588	9.66	8.92	+0.74	Ko	6, 3	-23	+18	-13	-9
589	10.48	9.58	+0.90	G5	2, 2	-9	+24		
590	9.19	8.87	+0.32	Fo	4, 3	-19	+1	-22	0
592	10.06	9.71	+0.35	F5	4, 1	-15	-1	0	-5
593	9.98	9.41	+0.57	Ko	5, 2	+5	+6		
594	9.95	9.59	+0.36	F5	3, 2	-17	+33	-4	+23
595	9.91	8.94	+0.97	G5	6, 4	-8	+5	-5	-10
596	10.67	9.70	+0.97	Ko	2, 1	-3	+27		
597	9.31	9.09	+0.22	Fo	8, 3	-16	+5		
598	9.90	9.40	+0.50	Fo	4, 1	-22	+36	-7	+21
600	10.31	8.91	+1.40	Ma	2, 4	+7	+5	+20	+1
603	8.26	7.98	+0.28	Fo	9, 6	-38	-14	-45	-24
605	10.50	9.76	+0.74	K2	2, 1	+22	+20	+32	+32
606	10.81	9.78	+1.03	K5	1, 1	+23	+30	+68	+41
608	10.29	9.53	+0.76	K2	3, 3	+14	+6	+26	+20
609	9.03	8.79	+0.24	A5	6, 4	-40	+9	-1	-7
610	8.16	7.20	+0.96	G5	6, 6	-13	-12	-22	-28
611	8.88	8.56	+0.32	F5	8, 6	-20	-3	-25	-23
612	9.16	8.24	+0.92	Ko	4, 4	-4	-2		
613	9.55	8.46	+1.09	K5	4, 4	-23	+2	-19	-15
615	10.37	9.49	+0.88	Ko	2, 2	+5	+4	+20	+11

TABLE II—*continued*

Kopff	IPg	IPv	C.I.	Sp.	No. of Obs.	Mt. Wilson		Yerkes	
616	8.31	7.33	+0.98	Ko	5, 5	+ 7	+ 2		
618	9.91	9.43	+0.48	Go	6, 3	0	+16	+16	+26
619	9.81	9.49	+0.32	F8	4, 2	-34	+11	-20	+16
620	8.39	8.27	+0.12	A3	8, 6	- 5	+ 2		
621	9.80	9.25	+0.55	G5	4, 2	-10	+10	+11	+ 7
622	9.65	8.67	+0.98	Ko	5, 6	- 3	+ 2	- 1	0
623	9.87	9.40	+0.47	Go	4, 2	-12	+13	+ 2	+ 8
624	9.25	8.83	+0.42	F8	7, 5	-23	+11	-31	-19
625	9.93	8.73	+1.20	K5	4, 4	-21	- 3	- 3	-24
626	8.46	8.45	+0.01	A2	6, 4	-37	- 2	- 7	- 9
627	9.38	9.05	+0.33	F2	4, 2	-50	+22	-26	0
628	8.82	8.54	+0.28	F5	7, 5	-14	+ 1		
630	9.52	8.70	+0.82	K2	6, 6	-16	+12	- 7	- 5
631	9.46	9.17	+0.29	Fo	6, 3	-15	- 3	- 4	+ 9
632	8.64	7.81	+0.83	Ko	8, 6	-10	- 6		
633	9.72	9.36	+0.36	F8	6, 3	- 5	+ 5	+25	+14
634	9.64	9.39	+0.25	A5	6, 1	+ 1	+15		
635	8.40	8.20	+0.20	A2	8, 6	-19	-14		
636	10.16	9.09	+1.07	K5	4, 2	+ 4	+14	+39	- 1
637	9.81	9.09	+0.72	Ko	6, 3	+ 1	+13	+12	+15
638	9.53	8.57	+0.96	Ko	4, 3	- 4	+ 5	+ 4	- 7
639	8.29	6.62	+1.67	K2	9, 8	-17	0	-13	+ 5
642	7.82	7.69	+0.13	A5	9, 7	-22	- 1	- 8	- 9
643	9.75	8.92	+0.83	Ko	4, 3	- 7	+ 2	+17	+18
644	9.45	9.11	+0.34	F5	6, 2	- 5	+ 3		
645	10.30	9.79	+0.51	Go	2, 1	- 1	+17	+21	+39
646	10.42	9.34	+1.08	Ko	2, 2	+14	0		
647	10.52	9.37	+1.15	K5	2, 2	+ 6	- 2	+23	+10
648	9.44	8.53	+0.91	Ko	4, 4	-23	+ 7	+12	+13
649	10.11	9.03	+1.08	Mo	4, 4	-11	+ 6	+14	+15
650	9.47	8.57	+0.90	Ko	4, 4	- 5	+19	+14	+11
651	9.96	9.05	+0.91	Ko	4, 2	- 5	+ 9	+ 8	+24
652	10.05	9.77	+0.28	F2	4, 1	+ 8	+32	+15	+10
653	9.77	9.07	+0.70	G	6, 2	- 3	+11		
655	9.71	9.20	+0.51	G5	4, 2	-19	+11	+14	+12
657	9.31	9.02	+0.29	F8	4, 2	-15	0	+10	+10
658	8.30	7.25	+1.05	G5	6, 6	+ 4	-21	-15	-13
659	9.63	8.68	+0.95	K2	4, 3	- 5	+14	+39	+ 2
660	10.25	9.39	+0.86	K5	3, 2	+24	0		
661	8.41	7.31	+1.10	Ko	9, 9	-23	-17	- 9	+ 6
662	8.99	7.88	+1.11	K5	6, 4	- 8	+ 6	+ 4	+ 3
663	9.80	8.94	+0.86	K2	6, 5	+ 5	+ 7		
664	7.87	7.86	+0.01	Ao	3, 2	-31	-13	-24	+ 7
666	9.42	9.11	+0.31	Go	4, 2	- 3	+15	+ 7	+ 4
667	9.55	8.47	+1.08	K2	4, 4	-20	+ 5	+28	+ 6
668	10.35	9.58	+0.77	K	1, 1	+75	+20	+54	+31
669	10.27	9.53	+0.74	K5	2, 2	+ 9	0	+21	+27
670	10.15	9.40	+0.75	Ko	3, 2	+19	+ 2	+39	+12
672	8.79	7.77	+1.02	Ko	8, 6	- 7	- 9		
673	9.94	9.70	+0.24	F8	1, 1	+ 9	+14	+23	+10

TABLE II—*continued*

Kopff	IPg	IPv	C.I.	Sp.	No. of Obs.	Mt. Wilson		Yerkes	
674	9.41	8.27	+1.14	K2	4, 4	-12	- 3	+21	+ 8
675	9.80	9.41	+0.39	F8	3, 2	- 5	+12	+16	+23
676	9.89	9.49	+0.40	Go	4, 1	-19	+ 8		
677	10.34	9.56	+0.78	K5	2, 2	+19	+14	+32	+50
678	8.82	7.19	+1.63	K2	3, 3			-18	- 3
679	10.00	9.37	+0.63	Go	1, 1	+44	+11	+26	+ 6
680	9.51	8.39	+1.12	K2	4, 4	-22	- 5	+12	+ 2
681	9.39	9.04	+0.35	F5	6, 3	- 8	+ 8	-14	+13
682	10.13	9.29	+0.84	K2	1, 1			+22	+17
684	10.03	8.57	+1.46	K5	3, 4	- 4	- 9	+18	+17
685	9.54	8.95	+0.59	G5	6, 3	-24	+ 7		
686	8.60	8.29	+0.31	F2	6, 4	-12	- 1	-11	- 8
688	9.77	9.49	+0.28	Go	3, 2	+ 4	- 2	+31	+11
689	9.63	8.07	+1.56	Ma	6, 6	+12	- 2		
690	9.26	8.91	+0.35	F5	4, 2	-21	- 6	-15	+10
691	9.22	8.71	+0.51	G5	2, 1			+11	+ 4
692	10.08	9.03	+1.05	K5	1, 1			+20	+16
693	9.31	9.09	+0.22	A5	6, 2	-22	+ 2		
696	9.67	8.15	+1.52	K5	4, 4	0	0		
697	8.91	8.44	+0.47	Go	6, 4	-21	- 8	- 3	+ 5
698	10.00	9.28	+0.72	F8	2, 1	- 4	+18		
699	9.81	9.44	+0.37	F5	1, 1	+21	+12	- 2	+16
703	9.32	7.89	+1.43	K2	4, 4	- 5	- 3	+ 5	+ 3
706	9.68	9.50	+0.18	F5	3, 1	+ 6	+15	+25	+ 4
714	9.06	8.31	+0.75	Ko	6, 4	- 2	- 5	- 5	+ 1
716	10.06	9.04	+1.02	Ko	2, 2	- 6	0		
717	9.87	9.58	+0.29	F5	1, 1	+24	+15	+ 7	+10
720	9.34	8.86	+0.48	G5	2, 1	-22	+ 6	-11	- 1
726	9.88	9.58	+0.30	F2	3, 1	- 8	+20		
727	9.55	9.02	+0.53	G5	4, 2	-11	+ 9		
728	9.12	8.25	+0.87	Ko	5, 4	-18	+ 6		
737	9.25	8.88	+0.37	F8	2, 1	-47	+10	- 8	+ 7
749	9.25	8.88	+0.37	F5	4, 2	-11	+ 7		
751	10.57	9.65	+0.92	Go	1, 1			+41	+53
752	9.54	8.22	+1.32	K5	4, 4	+ 8	+15		
757	9.86	9.51	+0.35	F8	2, 1	0	+16		
769	8.44	7.48	+0.96	Ko	5, 5	- 7	+15		
774	9.29	9.04	+0.25	A3	4, 2	-16	+13		
782	9.95	8.95	+1.00	K2	3, 2	+10	+ 4		
785	9.20	8.99	+0.21	A2	4, 2	+ 1	+ 3		
796	9.94	9.04	+0.90	Ko	3, 1	+12	+18		
798	10.04	9.36	+0.68	G5	1, 1	+30	+20		
813	10.12	9.24	+0.88	Ko	1, 1	- 7	+10		
818	9.21	8.85	+0.36	F8	2, 2	- 3	+ 8		
819	8.15	7.11	+1.04	Ko	3, 3	-29	+11		
820	9.60	9.01	+0.59	Go	2, 1	+ 1	- 1		
821	9.45	8.61	+0.84	G5	2, 2	-16	+21		

TABLE II—continued
(b) The Bright Extra Stars

HD	IPg	IPv	C.I.	Sp.	No. of Obs.	Mt. Wilson		Yerkes	C.I. _w
84117	5.64	4.95	+0.69	Go	1, 1	-10	-13		
84709	7.38	7.06	+0.32	F2	3, 3	-5	+9		+0.07
85043	7.10	6.67	+0.43	Fo	2, 3	-8	+2		+0.23
85725	7.00	6.28	+0.72	F8	2, 2	-14	+10		+0.22
85859	6.30	4.79	+1.51	Ko	3, 2	-24	-4		
85905	6.29	6.31	-0.02	A2	5, 6	-31	+2		-0.27
85951	6.76	4.96	+1.80	Ma	6, 3	-31	-15		
86030	8.55	6.90	+1.65	Ma	6, 6	-12	+24		
86266	6.50	6.28	+0.22	A2	1, 2	-15	+19		-0.04
86371	6.98	6.72	+0.26	Fo	4, 6	-41	+16		-0.41
86463	6.84	6.88	-0.04	A2	4, 6	-9	+11		-0.16
86612	5.93	6.05	-0.12	B5	3, 6	+5	+27		
86626	8.22	6.70	+1.52	K2	9, 7	-17	+1		
87019	7.84	6.82	+1.02	G5	8, 8	-13	+15		
87096	7.40	7.01	+0.39	F8	3, 3	-6	-4		+0.11
87130	7.02	6.93	+0.09	Ao	6, 9	+9	-23		+0.55
87318	6.71	6.79	-0.08	Ao	5, 9	-6	-3		+0.03
87427	6.04	5.80	+0.24	Fo	3, 4	+3	+6		+0.11
87768	6.92	6.81	+0.11	Fo	7, 9	-15	+8		-0.22
87793	7.63	7.18	+0.45	F8	8, 9	-11	+7		+0.01
87810	7.06	6.74	+0.32	F2	6, 8	+19	-16		+0.56
87808	7.25	5.61	+1.64	K2	8, 3	-22	-9		
87870	8.63	7.06	+1.57	Ma	14, 14	-1	-6		
88025	6.23	6.39	-0.16	Ao	2, 5	-29	-10		-0.21
88108	8.77	7.07	+1.70	Ma	6, 6	-3	+4	-8	
88182	6.40	6.28	+0.12	A2	4, 6	-17	+12		-0.09
88195	5.94	5.95	-0.01	Ao	2, 4	-34	+5		-0.26
88215	5.68	5.38	+0.30	Fo	2, 2	+8	-18		+0.46
88333	7.11	5.63	+1.48	Ko	4, 2	-37	+6		
88346	8.54	7.00	+1.54	K2	6, 6	+20	+20	-9	
88359	8.58	7.14	+1.44	Ko	9, 9	+14	+8	-21	
88372	6.27	6.32	-0.05	Ao	2, 6	-37	+8		-0.36
88549	7.13	7.21	-0.08	Ao	5, 6	-32	-3	-17	-0.23
88654	8.45	7.66	+0.79	G5	9, 8			+3	
88682	7.78	7.45	+0.33	F2	6, 5			-2	
88697	7.61	7.20	+0.41	F8	6, 6			-18	
88709	7.55	7.54	+0.01	A2	9, 8			0	
88764	7.96	6.96	+1.00	Ko	9, 9			-8	
88806	8.07	6.28	+1.79	Ma	9, 6	-9	+10		
88881	7.64	7.27	+0.37	F5	9, 8			-8	
88926	7.40	7.57	-0.17	Ao	9, 7			-17	
89033	7.27	6.10	+1.17	Ko	8, 5	-42	+2		
89057	7.65	7.86	-0.21	B9	9, 6			0	
89146	9.16	9.24	-0.08	Ao	7, 3			-11	
89254	5.58	5.32	+0.26	Fo	3, 3	-7	+4		+0.05
89351	8.02	7.03	+0.99	G5	6, 6	-14	+5		
89418	8.29	7.82	+0.47	Go	9, 6			+9	
89455	6.24	6.13	+0.11	Fo	2, 5	-8	-10		+0.03
89490	7.32	6.38	+0.94	Ko	9, 8	-42	-5		
89507	8.07	7.76	+0.31	F2	9, 6			+4	

TABLE II—*continued*

HD	<i>IP_g</i>	<i>IP_v</i>	<i>C.I.</i>	Sp.	No. of Obs.	Mt. Wilson		Yerkes	<i>C.I._w</i>
89565	6.63	6.40	+0.23	F2	4, 5	-29	- 6		-0.11
89604	9.67	9.18	+0.49	G5	3, 2			+ 6	
89669	7.10	7.05	+0.05	A2	8, 9	-51	-14	-10	+0.24
89670	7.45	7.29	+0.16	A5	6, 6			- 1	
89746	6.63	6.64	-0.01	A2	4, 6	- 6	-12		+0.13
89816	6.75	6.54	+0.21	A3	5, 8	-33	- 1		-0.08
89824	8.38	7.37	+1.01	G5	3, 3			-14	
89828	6.64	6.57	+0.07	A0	4, 8	-32	- 8		-0.03
89945	8.81	7.10	+1.71	Ma	6, 6	-18	+ 4	+10	
90027	6.78	6.87	-0.09	B9	6, 9	-30	+ 7		-0.27
90043	7.51	6.47	+1.04	G5	3, 3			-15	
90044	5.89	6.01	-0.12	B9	2, 5	-17	- 7		-0.03
90055	9.61	9.41	+0.20	F	2, 1			+ 9	
90057	8.21	6.37	+1.84	K5	6, 5	-10	- 6	+ 5	
90184	9.75	8.88	+0.87	K2	3, 3			+ 7	
90197	7.77	7.11	+0.66	G0	9, 8	-41	+12		
90212	7.88	7.87	+0.01	A0	3, 2			+ 6	
90362	7.27	5.59	+1.68	K5	6, 2	-36	- 7		
90374	8.82	7.74	+1.08	K2	6, 4			+ 3	
90430	7.00	7.06	-0.06	A0	4, 6	-35	-10	- 8	-0.17
90473	7.92	6.26	+1.66	K0	3, 2			+ 3	
90485	7.55	6.56	+0.99	K0	6, 6	-18	-14	+ 3	
90763	6.15	6.15	0.00	A0	2, 6	-20	-12		+0.06
90882	5.22	5.27	-0.05	B9	1, 2	+22	- 5		+0.41
90955	7.40	7.43	-0.03	A0	8, 8	-45	+ 6		-0.40
90954	7.35	7.16	+0.19	F0	8, 8	-11	+ 1		-0.03
91246	8.95	7.86	+1.09	K0	6, 4			+16	
91318	7.88	6.85	+1.03	K0	6, 6	-47	- 4		
91398	6.93	7.02	-0.09	B9	4, 5	-14	+ 8		-0.12
91550	6.95	4.95	+2.00	K2	4, 2	-35	+33		
91638	7.20	6.73	+0.47	F8	5, 6	-34	- 4		-0.09
91706	6.66	6.08	+0.58	F5	3, 4	-11	-24		+0.42
91975	8.53	6.87	+1.66	K5	5, 6	+10	- 5		
92098	8.35	7.33	+1.02	K0	5, 5	- 3	-12		
-10° 3030	10.10	9.81	+0.29		3, 1			- 1	
+ 0° 2649	10.00	9.58	+0.42		1, 1			+22	

Mount Wilson observers and partly to those stars whose photovisual magnitudes were given by Zug * and which are not included amongst the Kopff stars. The spectral types are taken from the Henry Draper Catalogue or from *H.B.*, 871. The spectral type of K541 (-14°3017) is F8. The type G5 given in the Yerkes and Mount Wilson tables results from a slip in *H.B.*, 871, where -15°2970 is numbered as K541 instead of K542.

Examination of the Overlaps.—Table III shows the zero point corrections which are implied by the differences between the determinations of magnitude on consecutive plates.

The rather elaborate procedure of obtaining these corrections used by the Mount Wilson observers was not employed. The $n-1$ differences from n overlapping plates provide $n-1$ equations to determine n zero-point corrections. The n th equation is provided by the assumption that the sum of the n corrections to be applied should be zero.

* *Ap. J.*, 73, 26, 1931.

TABLE III
Zero-point Corrections deduced from the Plate Overlaps

(Units 0 ^{m.01})						
Photographic				Photovisual		
Area	Comp.	Grating		Comp.	Grating	
		<i>m</i> < 9.0	<i>m</i> > 9.0		<i>m</i> < 8.0	<i>m</i> > 8.0
1	- 11	- 5	+ 1	0	0	+ 3
2	+ 6	- 3	+ 3	+ 1	0	+ 3
3	+ 2	- 2	- 2	+ 2	+ 1	+ 1
4	+ 5	+ 3	+ 3	0	+ 3	+ 5
5	+ 6	+ 3	+ 9	- 4	- 3	+ 5
6	- 7	+ 1	+ 2	- 8	- 3	+ 5
7	+ 4	- 1	- 2	- 6	0	- 2
8	- 3	+ 2	- 2	- 7	- 3	- 4
12	0	+ 5	- 2	- 1	- 3	0
13	- 7	- 2	- 7	0	- 2	- 3
14	+ 5	- 5	- 4	+ 7	+ 3	- 8
15	- 3	+ 3	- 3	+ 13	+ 3	- 6

The solution of these n equations is unique and can be found by simple arithmetic. The uniqueness of the solution implies that any errors in determining the differences between successive overlaps will enter into all the derived zero-point corrections.

It must be remembered that a pure "zero point error", *i.e.* a constant difference in the magnitudes, is rather rare. More often than not, the scale also differs so that the zero point error should be determined for at least two magnitude groups. In the case of the comparison plates, however, it did not seem feasible to divide the stars into two significant magnitude groups without unduly weakening the determinations of the differences between successive overlaps.

The zero-point corrections given in Table III were not applied. It will be noticed from the data for the grating plates how the zero point differences of the comparison plates have been very largely smoothed out by the simple process of taking means.

Plate Corrections.—An attempt was made to evaluate the distance corrections by arranging the differences of the individual magnitude determinations from their mean according to the position of the corresponding stars on the plate. Forty-nine squares, each 1° in side, were used, and the Kopff and the Bright Extra Stars were tabulated separately. Only the grating plates were examined. The magnitudes derived from the side and central images were not regarded as separate.

The material, though not sufficient for a thorough determination, did indicate, in the case of the photographic plates, the existence of a distance correction amounting to about 0^m.03 at 3° from the centre. For the photovisual plates the systematic effect, if any, is very much smaller. Table IV, which shows the mean values of this correction for the seven squares in each row and column gives an idea of its magnitude. The numbers in parentheses in this and subsequent tables are the numbers of the differences entering into the corresponding means.

TABLE IV
Corrections to be Applied for Position on the Plate
(Units 0^m.01)

x, y		-3°	-2°	-1°	0°	+1°	+2°	+3°
Photo-graphic	x	-3(52)	-1(87)	+1(157)	0(172)	0(108)	0(56)	-3(32)
	y	-2(64)	-1(81)	0(102)	+1(138)	0(121)	0(96)	-2(62)
Photo-visual	x	-0(47)	-2(75)	0(145)	0(163)	0(104)	+0(51)	+0(31)
	y	-1(61)	0(78)	0(90)	+0(123)	0(113)	+1(90)	-1(61)

No attempt was made to apply these corrections.

The mean of the magnitudes derived from the central and side images was used because of the systematic difference between these two magnitude determinations which is set out in Table V.

TABLE V

$m_{\text{central}} - m_{\text{side}}$ in Units of $0^{\text{m}}.01$

$m_c - m_s$			$m_c - m_s$			
C.I.	Photo.	Vis.	m	Photo.	Vis.	C.I.
-0.1	-10(17)	+7(24)	6.0		+ 3(11)	-0.08
+0.1	- 7(21)	+6(17)	6.5	- 5(6)	- 1(37)	+0.28
0.3	- 5(30)	+3(11)	7.0	- 6(19)	+ 1(54)	+0.48
0.5	- 3(17)	0(8)	7.5	-12(16)	+ 5(13)	+0.58
0.7	+ 7(12)	-2(2)	8.0	0(33)	+10(1)	+0.95
0.9	+ 3(20)	-4(11)	8.5	+ 3(54)		+0.89
1.1	+ 6(18)	+2(11)	9.0	+ 4(42)		+0.75
1.3	+15(5)	-4(5)	9.5	+10(4)		+0.87
1.5	+ 1(12)	-3(11)	10.0			+0.92
+1.7	+ 9(20)	-6(14)	10.5			+1.26

This systematic difference can be interpreted as due to a change in the value of the grating constant with colour or with magnitude, or possibly with both. The change with colour seems to be the more important. A similar change was noted in the previous paper. The systematic increase in mean colour with magnitude shown by the last column of Table V is sufficient to explain the greater part of the apparent change of grating constant with magnitude. This change was ignored during the reduction of the grating plates and so may have introduced a slight curvature into the apparent magnitude scale.

This curvature of the scale will not appear in that range of magnitude which has been obtained by direct comparison with the standard stars of the E regions and in which both side and central images have been measured, but it will appear in the magnitudes of the fainter stars which depend on that part of the reduction curve which has been derived from the side images only. If one compares the fifth and sixth columns of Table VI (i) one will notice that for the photographic magnitudes for which the effect is greatest this curvature sets in between 9.5 and 10.0. (Compare also Table VII of the previous paper.) Magnitudes of the very bright stars which have been derived from measures of side images only will also be affected. Here the correction will not be a general one, but will depend on the colours of the individual stars.

To test if the variation of grating constant with magnitude was a general phenomenon, a large number of differences central - side were examined for stars in the -30° to -35° zone taken from different parts of that zone. No systematic effect of appreciable size could be detected, though there were clear indications of local effects, effects which could probably be explained by the local distribution of the colour of the stars with magnitude.

The Probable Errors.—The probable error of a single determination of magnitude found from the residuals by means of the formula employed by the Mount Wilson observers was $\pm 0^{\text{m}}.062$ for the photographic and $\pm 0^{\text{m}}.043$ for the photovisual. It showed little variation either with the magnitude or with n , the number of determinations. This value of the probable error may be too small as the separate determinations are not all independent. If we confine our attention to the comparison plates which are completely independent, we find that the mean arithmetical difference between determinations on two separate plates is $0^{\text{m}}.116$ for the photographic and $0^{\text{m}}.072$ for the photovisual. The corresponding probable error of a single determination is $\pm 0^{\text{m}}.069$ for the photographic and $\pm 0^{\text{m}}.043$ for the photovisual. (These values include the zero errors, which in the light of Table III may be estimated at about $\pm 0^{\text{m}}.04$ for the photographic and $\pm 0^{\text{m}}.03$ for the photovisual.)

In spite of the good agreement between the two values of the probable error, it would seem wiser because of the lack of independence to divide the number of individual

determinations by a factor of two or three when determining the probable error to be associated with each magnitude in Table II. It must also be remembered that the magnitudes outside the range covered by the standard stars on the comparison plates are extrapolations by means of diffraction gratings and may well be subject to systematic errors larger than the accidental ones. It was in fact rather surprising to find that the individual determinations for the bright and faint stars were as consistent as those for the stars within the range of the standard magnitudes.

Comparison with the Yerkes and Mount Wilson Magnitudes.—The seventh and eighth columns of Table II show the differences between the Cape magnitudes and those determined at Mt. Wilson and at Yerkes, in the sense Mt. Wilson–Cape and Yerkes–Cape. The photographic differences precede the photovisual differences. The probable error of the Mt. Wilson and Yerkes magnitudes is given as about $\pm 0^m.09$ per single determination, while the number of determinations of magnitude for each star is roughly the same as for the Cape.

A glance at Table II will show not only large systematic differences between the various magnitudes but also what appear to be accidental differences far larger than the probable errors would suggest. Tables VI and VII show the systematic differences arranged according to Cape magnitude and colour, *b* indicating those stars with *C.I.* less than 0.40, *y* those with *C.I.* between 0.40 and 0.80, and *r* those with *C.I.* exceeding 0.80. The column headed “Comp. Plates” refer to the magnitudes as derived from the comparison plates only. These magnitudes will be on exactly the same scale as those derived for the cluster stars and will not be subject to accidental distortions of scale due to idiosyncrasies of the diffraction gratings.

TABLE VI
Comparison of Photographic Magnitudes
(i) Mt. Wilson–Cape

<i>m</i> ₉₉	<i>b</i>	<i>y</i>	<i>r</i>	All Stars	Comp. Plates
5.5	+ 7(3)	– 10(1)		+ 3(4)	
6.0	– 19(9)			– 19(9)	
6.5	– 21(8)	– 11(1)	– 28(2)	– 21(11)	– 15(5)
7.0	– 24(8)	– 9(4)	– 34(5)	– 23(17)	– 20(14)
7.5	– 17(4)	– 26(2)	– 30(2)	– 22(8)	– 24(9)
8.0	– 12(7)	+ 9(1)	– 19(9)	– 14(17)	– 14(17)
8.5	– 8(10)	– 4(3)	– 1(14)	– 4(27)	– 4(27)
9.0	– 15(22)	– 9(10)	– 7(10)	– 12(42)	– 11(26)
9.5	– 6(23)	– 9(16)	– 9(23)	– 8(62)	– 10(30)
10.0	+ 4(16)	+ 5(25)	+ 2(29)	+ 4(70)	– 8(8)
10.5		+ 24(14)	+ 18(24)	+ 20(38)	+ 13(2)

(ii) Yerkes–Cape

<i>m</i> ₉₉	<i>b</i>	<i>y</i>	<i>r</i>	All Stars
8.0	– 32(5)	– 43(1)	– 18(2)	– 30(8)
8.5	– 17(3)	– 40(1)	– 12(2)	– 19(6)
9.0	– 20(9)	– 12(5)	– 7(3)	– 15(17)
9.5	– 3(10)	– 7(7)	+ 6(12)	0(29)
10.0	+ 2(9)	+ 14(10)	+ 12(9)	+ 10(28)
10.5		+ 21(9)	+ 24(10)	+ 23(19)

(iii) Mt. Wilson–Yerkes

Uncorrected					Corrected			
<i>m</i> ₉₉	<i>b</i>	<i>y</i>	<i>r</i>	All Stars	<i>b</i>	<i>y</i>	<i>r</i>	All Stars
8.0	+ 13(5)	+ 52(1)	+ 3(2)	+ 15(8)	+ 3	+ 24	+ 9	+ 7
8.5	0(3)	+ 37(1)	+ 3(2)	+ 7(6)	– 4	+ 6	+ 18	+ 9
9.0	– 3(9)	+ 6(4)	– 2(2)	0(15)	– 4	+ 8	+ 9	+ 1
9.5	– 6(10)	– 5(7)	– 18(12)	– 11(29)	+ 2	– 7	– 8	– 4
10.0	– 2(9)	– 10(10)	– 18(7)	– 9(26)	+ 4	+ 1	– 9	– 1
10.5		+ 4(9)	+ 5(9)	+ 4(18)		+ 2	– 1	+ 1

TABLE VII
Comparison of Photovisual Magnitudes

(i) Mt. Wilson-Cape					
m_{pv}	b	y	r	All Stars	Comp. Plates
5.0		-13(1)	+5(3)	+1(4)	
5.5	-6(3)		-3(3)	-5(6)	
6.0	+5(9)	-7(2)	+6(2)	+4(13)	+8(4)
6.5	-4(9)	-1(2)	-5(5)	-4(16)	-2(13)
7.0	-1(11)	+10(2)	+3(13)	+2(26)	+2(28)
7.5	+1(3)	-19(1)	-8(7)	-7(11)	-4(10)
8.0	-10(10)	+2(3)	+1(19)	-2(32)	-1(29)
8.5	-1(12)	-1(7)	+6(18)	+2(37)	+1(36)
9.0	+9(27)	+9(20)	+9(34)	+9(81)	+11(18)
9.5	+14(28)	+13(29)	+12(22)	+13(79)	

(ii) Yerkes-Cape				
m_{pv}	b	y	r	All Stars
6.0			+3(1)	+3(1)
6.5			0(4)	0(4)
7.0	-9(5)	-18(1)	-10(8)	-10(14)
7.5	-5(5)	-12(2)	-2(3)	-5(10)
8.0	-12(8)	-9(2)	-2(7)	-7(17)
8.5	-14(6)	+3(3)	-1(12)	-4(21)
9.0	+4(11)	0(11)	+8(12)	+4(34)
9.5	+12(14)	+22(15)	+18(8)	+17(37)

(iii) Mt. Wilson-Yerkes				
m_{pv}	b	y	r	All Stars
6.5			-11(3)	-11(3)
7.0	+3(3)		+12(6)	+9(9)
7.5	+8(1)	+7(1)	-23(1)	-3(3)
8.0	+4(6)	+10(1)	+4(6)	+4(13)
8.5	+12(6)	-10(2)	+4(12)	+5(20)
9.0	+2(10)	+11(9)	-1(10)	+4(29)
9.5	+1(13)	-9(14)	-3(7)	-4(34)

TABLE VIII
Difference in Zero Points

(Units 0 ^m .01)									
Field	No.	Mt. W.-Y.		Y.-C.		Mt. W.-C.		Mt. W.-C. (All Stars)	
		P_g	P_v	P_g	P_v	P_g	P_v	No.	P_g P_v
1	32	-13	-7	+8	+9	-5	+2	40	-8 0
2	40	-17	-6	+11	+11	-6	+5	53	-11 +2
3	39	-16	0	+6	+8	-10	+8	51	-15 +6
4	39	-8	+6	-1	0	-9	+6	51	-11 +4
5	43	+14	+9	-14	-6	0	+3	58	-3 +2
6	28	+22	+6	-14	-3	+8	+3	59	+5 +3
7	12	+31	+9	-24	-4	+7	+5	64	+4 +6
8								99	+2 +8
12								81	+1 +11
13								61	-4 +8
14								49	-7 +6
15								46	-8 +6

The Mt. Wilson observers noticed that part of the large difference between the Yerkes and Mt. Wilson photographic magnitudes could be attributed to a progressive change in zero point. This clue is followed up in Table VIII. It is of course impossible to tell

on which Mt. Wilson and Yerkes plates the stars occur, but the close agreement of columns three and four of Table VIII with the columns A–Y of Table IX of the Mt. Wilson paper indicate that our results are comparable with theirs. The change in zero point that they suspected is fully confirmed by the Cape magnitudes, though the differences Yerkes–Cape run rather more smoothly and show a larger systematic effect than do the Mt. Wilson–Cape differences. This effect can be investigated more easily by arranging the stars in order of declination and, in view of systematic scale effects, in order of magnitude. This is done in Table IX. Only the Kopff stars are included. The line -3° includes all stars north of $-5^{\circ} 59'$; -9° those between $-6^{\circ} 00'$ and $-11^{\circ} 59'$ and so on.

TABLE IX
Differences in Zero Point according to Magnitude and Declination
(Units $0^m.01$)

		Kopff Stars								
		Mt. Wilson–Cape			Yerkes–Cape			Mt. Wilson–Yerkes		
m_{pg}		< 9	9	10	< 9	9	10	< 9	9	10
Dec.										
0										
– 3		– 17(6)	– 8(21)	+ 19(7)	– 13	+ 9	+ 28	– 4	– 17	– 9
– 9		– 28(6)	– 17(20)	+ 7(8)	– 19	– 1	+ 23	– 9	– 16	– 16
– 15		– 2(8)	– 6(13)	+ 26(12)	– 31	– 25	+ 11	+ 29	+ 19	+ 15
– 19		– 5(6)	+ 3(30)	+ 12(13)						
– 23		– 8(13)	– 7(29)	+ 11(17)						
– 25		– 2(4)	– 4(17)	+ 8(11)						
m_{pv}		< 8	8	9	< 8	8	9	< 8	8	9
Dec.										
0										
– 3		– 11(5)	– 1(12)	+ 9(17)	+ 1	+ 6	+ 15	– 12	– 7	– 6
– 9		– 3(1)	+ 6(13)	+ 15(19)	– 10	– 9	+ 17	+ 7	+ 15	– 2
– 15		– 11(5)	– 4(13)	+ 10(15)	– 22	– 12	+ 7	+ 11	+ 8	+ 3
– 19		– 5(3)	+ 2(17)	+ 9(29)						
– 23		0(7)	+ 7(18)	+ 14(34)						
– 25		+ 8(1)	+ 5(14)	+ 13(17)						

The most interesting part of Table IX is the Yerkes–Cape columns which show a marked declination effect for both photographic and photovisual magnitudes. This effect is in the sense that the lower the stars are in the sky at Yerkes, the brighter they appear. This rather remarkable phenomenon is confirmed by the Mt. Wilson magnitudes, though the increase in brightness with declination that these imply is not so regular.

The Mt. Wilson–Cape differences are neither so large nor so systematic as the Yerkes–Cape differences, though these for the -9° zone do stand out. These differences should be large enough to show up as irregularities in the colour indices. That they do can be seen from Table X which shows for each zone the average difference of the Mt. Wilson and Yerkes colour indices from the mean colour indices given in Table XI of the Mt. Wilson paper and Table 3 of the Yerkes paper. In calculating these average differences of the colour indices, all types were included, even though the mean colour index of a late type star seems to be an ambiguous quantity. (In the case of the outstanding Mt. Wilson -9° zone, the average departure of the colour indices from their respective means is $-0^m.19$ for the early types and $-0^m.26$ for the later types.)

A careful comparison of Table X with the differences of the corresponding columns of Table IX suggests that the origin of by far the greater part of the zero point differences of Table IX lies in the Yerkes and Mt. Wilson magnitudes.

A possible cause of the large zenith distance effect in the Yerkes magnitudes suggests itself. At the latitude of Yerkes, stars south of -5° declination culminate below the height of the Pole. A considerable correction will therefore be needed to the measured

TABLE X
Variation in Mean Colour Index with Declination
 C.I.

Dec.	Mt. Wilson	Yerkes
°	m	m
- 3	-0.03	0.00
- 9	-0.23	-0.06
-15	+0.09	-0.09
-19	+0.05	
-23	-0.02	
-25	-0.05	

magnitudes of the stars at -16° and -17° which must have been measured at least 10° below the height of the Pole. From the fact that the magnitudes given for such stars are too bright one must conclude either that the magnitudes have been grossly over-corrected by means of the usual secant zenith distance law, which seems most unlikely, or that this law does not apply to these measures.

One of the points stressed by Ross and Zug in the description of their apparatus is the small size and perfection of the star images formed by their lenses. These images were measured by means of a comparison scale. As stars were recorded to about $13^{\text{m.9}}$ on the photographic plates and $12^{\text{m.1}}$ on the photovisual ones, it seems safe to assume that for the stars with which we are concerned the images would be fully "burnt out" and the measures by means of the comparison scale would depend mainly on the size of the image. Now in spite of the short focal length, the size of the image will depend to some extent on the seeing, which normally deteriorates with increasing zenith distance. The poorer the seeing, the bigger the image. Thus it appears quite possible with such equipment to measure stars low in the sky as brighter than they really are. Such an effect can be expected to depend on the magnitude and, to a lesser extent, on the colour of the stars concerned.

Another possible cause is the application of inadequate distance corrections. The effects of erroneous plate corrections would be greatest at the end of the observed part of the Eros path, where magnitudes obtained from one plate are not checked by those obtained from an overlapping plate. It is unfortunate that the Yerkes observers have published no account of just what distance corrections were applied to their measures.

Unfortunately, it seems probable that something of this large systematic effect in the Yerkes magnitudes has been carried over into the Mt. Wilson magnitudes. It will be recalled that the Mt. Wilson observers were faced with large systematic corrections depending on the position on the plate. The preliminary evaluation of this correction had to be made from the Yerkes magnitudes of stars which were arranged in a zone 2° wide running very approximately north and south across their plates. To quote the Mt. Wilson paper.

"Since the correction depends on the size of the image as well as its position on the plate, separate tables were prepared for the magnitude limits 8, 8-9, 9-10, and 10 for both photographic and photovisual results. The corrections are all asymmetrical with respect to the centre, especially so for mag. 8-10 on the plates of the photographic series, for which the corrections range from about $+0.5$ to -0.3 mag. in opposite halves of the plate. The change with brightness near the tenth magnitude is rapid, particularly in the northern half of the field, and failure to use the exact value of the correction may have introduced a slight discontinuity into the scale of the adopted photographic magnitudes at this point. A similar irregularity may also affect stars near the eighth magnitude, where the transition from the one group to the next is not well determined. The corrections to the photovisual results are smaller than those required by the photographic magnitudes, show less asymmetry with respect to the centre of the plate, and present some resemblance to what might normally be expected in the way of a distance correction".

Since the basic cause of this distance correction "seems to be an error in the centring of the lenses of the Cooke triplet which seriously affects the photographic rays but has little influence on the light transmitted by the yellow filter", it is not improbable that for the photographic magnitudes its size will depend also on the colour. The material available—the hundred-odd Kopff stars with their restricted range of magnitude and colour—does not seem to have been sufficient to determine such a variation of the plate corrections with colour. Failure to take account of it may have affected the photographic magnitudes of the Bright Extra Stars of early spectral type. It will be noticed from the ninth column of Table II, which gives for these stars the variation of the Mt. Wilson colour index, from its adopted mean that there are some extraordinarily large variations which, in most cases, are not confirmed by the Cape colour index. Moreover, these variations are more closely correlated with the differences between the Mt. Wilson and Cape photographic magnitudes than with the differences between the photovisual values.

In view of the large systematic errors that effect both the Mt. Wilson and Yerkes magnitudes of the Eros Comparison Stars it would appear that neither series can be regarded as an accurate representation of the International Scale as embodied in the North Polar Sequence. In an attempt to harmonise these two sets of magnitudes to form a common base to which the Cape magnitudes could be reduced, the zero point differences between the Mt. Wilson and Yerkes magnitudes were removed plate by plate. The resulting scale relations are shown in Table VI under the heading "Corrected". These scale relations are only slightly smoother than they were before the zero differences were removed while the large colour effect is, if anything, increased. The attempt to reconstruct the scale of the Polar Sequence was therefore abandoned and it was decided to print the Cape magnitudes as they stood.

It will be noticed from Table VII that the Cape photovisual magnitudes—about which most doubt was felt—agree fairly well with the Mt. Wilson magnitudes until the ninth magnitude is reached. There may indeed be a slight colour difference between them, but this is less than the colour difference between the Yerkes and Mt. Wilson magnitudes.

Table VI on the other hand shows that there are large systematic differences between the Cape and Mt. Wilson photographic magnitudes. These seem to be mainly of the nature of scale differences, though for the brighter stars there are signs of a colour difference in the sense that red stars are measured relatively fainter on the Cape system. The irregularity in the scale differences between $8^m.0$ and $9^m.0$ can probably be attributed to the Mt. Wilson magnitudes. The rapid changes near the tenth magnitude may also be due to them, though they are as likely to be due to a systematic error in the Cape magnitudes. The mean difference Mt. Wilson–Cape for stars between $7^m.0$ and $9^m.0$ is about $-0^m.13$.

It might appear that the effect of the erroneous plate corrections applied to the Mt. Wilson measures would cancel out when a large number of stars are considered and that in the mean the scale and zero point of the Mt. Wilson magnitudes would be that of the Polar Sequence on which they are based. This is not necessarily the case, however, as these plate corrections were also applied to the measures of the polar stars, which presumably were always photographed on the plate in about the same position. The erroneous plate corrections will therefore produce systematic effects on the adopted scale. This effect is likely to be relatively greater for the brighter stars of the sequence which are situated at a greater distance from the pole than are the fainter ones.

Relation between Colour Index and Spectral Type.—Both the Yerkes and Mt. Wilson observers comment on the apparently large spread in the colour indices associated with a given spectral type. There is a similar though much smaller spread in the Cape colour indices. This spread may be real (absolute magnitude effects, etc.) or it may be due to errors in the colour indices or in the spectral classification. The distribution of Cape colour index with Harvard spectral type is shown in Table XI. To minimise the effect of accidental errors in the colour indices, only those stars whose photographic and

photovisual magnitudes both depend on at least two observations were included in this classification.

TABLE XI
Distribution of Colour Indices with Spectral Type

Sp. C.I.	Ao	A2	A5	Fo	F2	F5	F8	Go	G5	Ko	K2	K5	Ma
-0.25	1												
0.15	3												
-0.05	9	3											
+0.05	5	4											
0.15		2	5	6									
0.25		3	2	11	1	3	2	2					
0.35				4	6	12	9	1	1				
0.45				1		2	9	9	3	1			
0.55						1		2	6	1			
0.65								1	2	1			
0.75							1		4	6	2	2	
0.85							1		3	11	4	3	
0.95									6	15	3	1	
1.05									5	12	4	3	
1.15										2	3	4	
1.25										1	2	3	
1.35											2	3	
1.45										2	2	3	1
1.55										1	2	1	3
1.65										1	3	2	2
1.75													3
1.85												1	1
1.95													
+2.05											1		

If for each spectral division there were but one corresponding value of the colour index we should expect to find the observed colour indices clustering about a mean value with a mean deviation which should be not much greater than 0^m.07. These conditions seem to be satisfied only for the F types. For the other early types, the average deviation about the mean falls within the prescribed limit, but there is no marked sign of clustering about the mean value, perhaps through the lack of an adequate number of stars. For the later types, the apparently large spread in the colour indices tends to disappear if one arranges the stars in magnitude groups and remembers that each of the HD types used is composite, not only of giants and dwarfs but also of two or three adjacent sub-types. The outstanding colour indices are mostly for bright stars. The colour indices of the stars classified in *H.B.*, 871, do not differ significantly from those classified in the Henry Draper Catalogue.

The mean values of the colour index for types Go and earlier are given in Table XII, the number of stars on which each mean depends being in parentheses. The corresponding average deviations are given in units of 0^m.01. The columns headed Carr refer to the values found by Carr* from measures made on some of the more northern Yerkes plates. The second column gives the value of C_s , the colour index inferred from the spectral type, as given by Seares and Joyner.† In comparing the average deviation associated with each mean it must be remembered that the Yerkes values refer to Kopff stars only—that is, to a more restricted range of magnitudes than do the others.

In view of Martin's‡ remarks on the colour index of Ao stars as derived from observations of the Eros stars and Seares'§ reply, it seems worth while to examine the Ao stars individually. Table XIII gives the colour indices of all the Ao stars included in the

* *Ap. J.*, 76, 70, 1932.

† *M.N.*, 102, 263, 1942.

‡ *Ap. J.*, 98, 276, 1944.

§ *M.N.*, 103, 281, 1943.

Mt. Wilson and Cape lists, those depending on a single determination of magnitude being indicated by a colon.

TABLE XII
Mean Colour Indices

Sp.	C_s	Cape		Mt. Wilson		Yerkes		Carr	
		C.I.	A.D.	C.I.	A.D.	C.I.	A.D.	C.I.	A.D.
B ₅	-0.39	-0.12(1)		-0.34(1)				-0.27(4)	16
B ₈	-0.29	-0.04(1)		-0.26(2)		-0.30(3)	1	-0.22(4)	18
B ₉	-0.23	-0.14(5)	5	-0.19(5)	19	-0.08(3)	4	-0.18(15)	13
A ₀	-0.15	-0.05(18)	6	-0.14(21)	23	-0.15(31)	11	-0.05(40)	12
A ₂	-0.05	+0.08(12)	8	-0.08(13)	17	-0.03(17)	12	+0.02(18)	12
A ₃	-0.02	+0.19(3)	5	-0.03(3)	6	+0.13(5)	12	+0.19(5)	4
A ₅	0.00	+0.17(7)	7	-0.02(9)	7	+0.16(13)	9	+0.08(6)	22
F ₀	+0.12	+0.25(22)	6	+0.10(26)	16	+0.21(24)	9		
F ₂	+0.16	+0.31(7)	2	+0.11(13)	17	+0.27(32)	15		
F ₅	+0.26	+0.36(18)	5	+0.29(27)	15	+0.24(58)	12		
F ₈	+0.35	+0.38(21)	4	+0.26(33)	11	+0.30(47)	13		
(F ₈)		+0.78(2)	6						
G ₀	+0.42	+0.45(15)	7	+0.37(27)	12	+0.45(52)	16		

TABLE XIII
Colour Indices of A₀ Stars

m	Cape	Mt. Wilson	Yerkes	m	Cape	Mt. Wilson	Yerkes
6.2	.00	-.08		6.0	-.01	-.40:	
6.3	-.05	-.50		6.4		-.35	
6.4	-.16	-.35		7.4		-.59	
6.6	+0.07	-.17		7.6	-.17		
6.8	-.08	-.11		7.9	+0.01	-.17:	-.30
6.9	+0.09	+0.41		7.9	+0.01		
7.1	-.06	-.31		8.7		+0.09	
7.2	-.08	-.37		8.9	-.15:	-.26	
7.4	-.03	-.54		9.2	-.08		
8.1	-.02	+0.20	-.17	9.7	+0.03:	-.31	
8.3	-.11	-.06	-.21	10.2		-.33	
8.7	-.20	-.17		10.4		+0.00	
8.7	-.02	+0.25					
Mean	-.05	-.14					
A.D.	.06	.22					

If we confine our attention to the thirteen stars for which both the Mt. Wilson and Cape colour indices depend on more than one observation of magnitude, we get as the mean colour index of an A₀ star -0^m.14 on the Mt. Wilson system and -0^m.05 on the Cape, the corresponding average deviations being 0^m.22 and 0^m.06. It will be noticed that few of the very large deviations of the individual Mt. Wilson colour indices from their mean value are substantiated by similar deviations in the corresponding Cape colour indices. It is tempting therefore to attribute these large deviations to errors in the Mt. Wilson magnitudes and to agree with Martin that "this result (-0^m.14 for the colour index of an A₀ star) upon which a great deal has been based and which is now becoming widely quoted, has a large probable error and it would seem that too great an accuracy has been attributed to it". That the value of -0^m.14 happens to be close to the value found from a discussion of the polar region must be regarded as a fortunate accident, not as a proof of the reliability of the Mt. Wilson magnitudes of the Eros stars. It seems strange that neither Martin nor Seares should have mentioned the value of -0^m.05 obtained by Carr from measures of 40 A₀ stars situated in the central portions of the plates taken by Ross and Zug.

The value found from the Cape observations cannot be interpreted until the relation between the Cape and international magnitude systems has been established. If we adopt the mean difference of $-0^m.13$ that was found between the Mt. Wilson and Cape photographic magnitudes as a zero point correction to the Cape magnitudes, the mean *C.I.* of an A0 star, as found from the Cape observations becomes $-0^m.18$, while the general agreement between the Cape *C.I.* and C_s is greatly improved except for the F8 and G0 stars.

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ON THE RELATION OF THE CAPE MAGNITUDES TO THE INTERNATIONAL SYSTEM

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Summary

This paper gives the results of further observations of the Pleiades and of a comparison of the Cape photographic magnitudes of stars in the Pleiades, the Hyades and Præsepe with the corresponding Harvard magnitudes obtained by direct comparison with the Polar Sequence. A comparison is also made between some Mount Wilson and Cape colour indices. It is concluded that the Cape photographic magnitudes probably need a zero-point correction of $-0^m.13$, though no satisfactory reduction to the International System is possible until further work has been done in the Northern Hemisphere. The use of diffraction gratings in photometry is discussed. The paper concludes with a brief outline of a general plan to secure a consistent system of magnitudes.

Introduction.—This paper may be regarded as a continuation of “Standard Magnitudes at -45° ” * and, like that paper, is principally concerned with finding a method of reducing the measured magnitudes of 13,000 stars in the -30° to -35° zone to the International System. It will be recalled that the Cape system of magnitudes was evolved from an attempt to bind the Harvard magnitudes for sequences of stars in the nine standard E regions into one homogeneous system. Scale, colour and zero-point corrections to this system were obtained from a series of plates of the Pleiades, Hyades and Præsepe. The six pairs of plates for each of the Hyades and Præsepe were of good quality, but three pairs of those used for the Pleiades were not. When, therefore, a mean difference of $0^m.13$ between the Mount Wilson and Cape photographic magnitudes for the Eros stars was found †, it seemed well worth while to get some more plates of the Pleiades which had been the deciding factor in the adoption of the zero-point as found from the observation of the Hyades, rather than that found from Præsepe.

Re-observation of the Pleiades.—Three pairs of plates comparing the Pleiades with E4 were obtained in January 1944 under what appeared to be good observing conditions. These were used to supplement the three pairs of good plates previously measured. The measures of these latter plates were reduced afresh, differential extinction corrections being applied to the standard stars in E4 and E9. The resulting photographic magnitudes are smaller than those given in Table XXIV of the former paper * by $0^m.07$, but show no appreciable difference in scale from them. Accepting these new magnitudes, the correction required by the Cape photographic magnitudes to make them agree with the Hertzsprung ones is $0^m.08$. Thus the discrepancy between the corrections derived from the Præsepe and Pleiades observations is increased by these new (and presumably better) observations.

It is not easy at the Cape to get reliable plates of the Pleiades. Their minimum zenith distance is 58° and it is only feasible to compare them with E9 or E4. The com-

* M.N., 103, 288, 1943.

† M.N., 104, 313, 1944.

parison with E₉ is open to the objection that at the time of comparison the standard region is low over Table Mountain (angle of elevation of Devil's Peak 14°), where the seeing is noticeably worse than in other parts of the sky. Moreover, at 60° zenith distance differential colour effects begin to be important, as was very noticeable from the residuals for the stars in the standard sequences. In the case of E₄ it was possible to use a sequence of stars with colours very similar to those of the Pleiades and to ignore the redder stars. This was not possible for E₉, in which most of the standard stars are redder than the average Pleiad.

Of the six plates actually used to derive the new magnitudes, four were comparisons with E₄ and two with E₉. The zero-point residuals for each plate from the mean of the six averaged 0^m.11. The actual values were -0^m.13, +0^m.09, -0^m.02, -0^m.18, +0^m.13 and +0^m.11, the last two referring to the E₉ plates. These residuals are disappointingly large, as the plates were taken under seemingly good observing conditions. (For the Hyades and Præsepe plates the corresponding residuals averaged only 0^m.03.) The large zenith distance (60°) at which the observations had to be made may be the principal cause of this poor result. In pleasing contrast with the zero-point residuals are the residuals for the individual magnitudes. After these have been cleared of the constant zero-point difference for the plate they average only 0^m.04—that is about the same as for the Hyades and Præsepe observations and a little less than the value that would be deduced from the Eros comparison stars observations.

It will be noticed that the magnitudes derived from the four E₄ plates differ by 0^m.18 from those derived from the two E₉ ones. This difference may be systematic or it may be accidental. In either case we are likely to get the most reliable result by assigning equal weights to each of the six plates and taking a straight mean, since comparisons with E₄ seem to be entitled to more weight systematically than those with E₉.

Comparison with the Harvard Magnitudes.—After the above work was finished a long-awaited copy of Harvard Observatory Mimeograms, Series I, No. 2, was received. This mimeogram gives the photographic magnitudes of stars brighter than 8.25 between declination +25° and +15°. These magnitudes have been obtained by direct comparison with the Polar Sequence and are believed to be on the International System. Most of the stars brighter than 9^m.0 that I have measured in the three clusters are included in this catalogue. Unfortunately the accidental differences between the Cape and Harvard magnitudes, which average 0^m.16, are too large to justify a detailed investigation of scale and colour differences for each cluster. If we confine our attention to those stars for which $\frac{1}{2}(m_{\text{Cape}} + m_{\text{Harv.}})$ lies between 7^m.5 and 8^m.5, we get the following differences in zero-point:—

From	9	stars in the	Hyades,	Harv.	- Cape	= +0 ^m .04
„	17	„	Præsepe,	„	„	- 0 ^m .02
„	6	„	the Pleiades,	„	„	+ 0 ^m .02
„	11	„	„ Pleiades,	„	„	+ 0 ^m .17

In the case of the Pleiades, the first group of six stars refer to those whose magnitudes were determined from the same set of plates as the main body of the stars in the mimeogram, the second group of those whose magnitudes were marked *P* in the mimeogram. According to the introduction these magnitudes were determined independently, because the field surrounding the Pleiades is too crowded for measurement on the plates taken with the Ross 3-inch lens. (They seem to be those given by Miss Leavitt in *H.A.*, 71, corrected according to the *H.B.* 781, 1923.)

The new Harvard observations appear therefore to confirm the zero-point of the Cape magnitudes at 8^m.0. They do not confirm their scale. Treating all the clusters together but leaving out the old Harvard Pleiades magnitudes we get the result shown in Table I, which gives the differences *HP* - *IPg* arranged both according to the Cape magnitudes

and according to the Harvard magnitudes. The number of stars on which each entry depends is shown in parentheses.

TABLE I

HP - IP_g

<i>m</i>	6.5	7.0	7.5	8.0	8.5	9.0
Cape	-0.05(2)	-0.19(10)	-0.15(9)	+0.02(15)	-0.02(16)	-0.26 (1)
Harv.	-0.25(7)	-0.12(7)	-0.12(7)	-0.02(12)	-0.01(20)	
Mean	-0.15	-0.16	-0.14	0.00	-0.01	

The mean differences shown in Table I are somewhat similar to those found between the Mount Wilson and Cape magnitudes for the Eros stars, though the scale difference they imply is even larger. The scale of the Cape photographic magnitudes is that found from the cluster comparisons. All three clusters gave accordant results. The scale for the Hyades depends only on Hertzsprung's grating observations *, but that for the Pleiades depends on several different observers and is more or less confirmed by Calder's photo-electric observations.† For Præsepe the independently determined scales of Hertzsprung ‡, Schilt § and Haffner || are in substantial agreement for the range of magnitudes with which we are concerned. The scales of Hertzsprung and Schilt depend on diffraction gratings, but Haffner's was obtained by means of platinum filters and should be trustworthy.

It is possible to get some idea of the reliability of the various sets of magnitudes from triangular intercomparisons. Such comparisons give (after the zero-point differences have been removed) the following average deviations for the observed magnitudes of the individual stars:—

		<i>m</i>
For Præsepe (24 stars)	{	Haffner 0.02
		Hertzsprung 0.03 (11 stars only)
		Harvard 0.16
		Cape 0.03
For the Hyades (18 stars)	{	Hertzsprung 0.02
		Harvard 0.12
		Cape 0.02

For the Pleiades, the scale of the old Harvard magnitudes agrees with that of other observers, while their average deviation is only 0^m.05. In view of the obviously large accidental errors of the new Harvard magnitudes, I am not inclined to assign much weight to the comparison shown in Table I, even though its result is supported to some extent by the Mount Wilson magnitudes for the Eros stars.

The large accidental errors of the new Harvard magnitudes is rather surprising since they were obtained with the same apparatus as the *HP* photographic polar magnitudes ¶ for which Seares found an average deviation of about 0^m.05.** On the other hand, the Gaposchkins have already found for this set of Harvard magnitudes a mean zero-point error for a one-hour group of 0^m.15.††

* *A.N.*, 209, 115, 1919.

† *H.A.*, 105, 453, 1937.

‡ *A.N.*, 205, 71, 1917.

§ *Trans. Yale U.O.*, 10, 1934.

|| *Ver. Göttingen*, 54, 1937.

¶ *H.B.*, 881, 1931.

** Seares, Ross and Joyner, *Magnitudes and Colours of Stars North of +80°, Carnegie Institution of Washington, Publication 532, 1941* (also referred to as "The Mount Wilson Polar Catalogue").

†† *H.B.*, 902, 1936.

Comparison of Colour Indices.—A large scale difference in the photographic magnitudes should show itself in the colour indices. From this point of view it is interesting to compare Table XXVI of the previous paper with Table II, which shows similar data taken from the Mount Wilson Polar Catalogue. Table III shows the resulting differences for all entries in which more than three Mount Wilson stars are included in the mean.

TABLE II

Mount Wilson Polar Catalogue

Variation of Colour Index with Photovisual Magnitude and HD Spectral Type

$\frac{m}{\text{Sp.}}$	5.8	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.2
B ₉			— .21(1)		— .17(4)	— .16(4)	— .17(1)		
A ₀	— .05(2)	+ .03(3)	— .08(6)	— .08(9)	— .06(8)	— .07(9)	— .09(3)	— .10(9)	
A ₂	+ .11(1)	+ .04(3)	+ .04(4)	+ .03(4)	+ .03(5)	.00(6)	+ .01(10)	+ .07(5)	
A ₃	+ .21(1)	+ .13(1)		+ .16(1)	— .01(2)	+ .03(4)	— .02(7)	+ .14(5)	
A ₅			+ .24(1)	+ .07(3)		+ .07(7)	+ .12(3)	+ .04(5)	
F ₀	+ .14(1)		+ .19(3)	+ .21(4)	+ .17(7)	+ .12(9)	+ .14(13)	+ .12(6)	
F ₂	+ .34(1)		+ .30(2)	+ .30(4)	+ .29(3)	+ .20(3)	+ .15(8)	+ .08(2)	+ .13(1)
F ₅		+ .28(1)	+ .30(2)	+ .31(3)	+ .30(3)	+ .22(9)	+ .20(8)	+ .24(7)	+ .13(2)
F ₈			+ .46(2)	+ .44(2)	+ .38(7)	+ .33(10)	+ .33(11)	+ .34(6)	
G ₀	+ .54(1)			+ .51(4)	+ .55(6)	+ .44(6)	+ .41(13)	+ .35(3)	
G ₅	+ .76(2)	+ .92(1)	+ .90(6)	+ .85(9)	+ .85(18)	+ .85(24)	+ .77(20)	+ .71(10)	+ .25(1)
K ₀	+ 1.11(7)	+ 1.21(5)	+ 1.08(8)	+ 1.05(18)	+ 1.11(23)	+ 1.08(37)	+ 1.04(23)	+ .88(6)	
K ₂	+ 1.54(2)			+ 1.29(5)	+ 1.18(7)	+ 1.33(7)	+ 1.38(10)	+ 1.35(1)	
K ₅	+ 1.43(1)	+ 1.31(1)		+ 1.56(2)	+ 1.44(2)	+ 1.57(6)			
Ma	+ 1.61(1)	+ 1.61(1)	+ 1.53(1)			+ 1.75(4)	+ 1.62(3)		

It will be seen that, within the limits of magnitude in common and for stars G₀ and earlier, the variation in colour index with magnitude is essentially the same, but the North Polar colour indices are about 0^m.12 smaller than the corresponding Cape Zone ones. This difference does not vary with magnitude or type in a way that would suggest that there was either a big scale or colour difference between the two sets of magnitudes. It does suggest a zero error in either the Cape photographic or photovisual magnitudes, presumably in the former. This evidence is not decisive, however, because of possible systematic differences in the spectral classification; the classification of the Polar Cap was done from plates taken at Cambridge, while that for the Cape Zone would be done from plates with smaller dispersion taken at Arequipa.

The lower part of Table III shows the result of grouping the A and F stars and applying the systematic correction δC found by Seares and Joyner* in their discussion of the Polar Catalogue. A–F (cor.) shows a certain resemblance to what might be expected from Table I, or from the comparisons of the Cape magnitudes for the Eros star with those of Mount Wilson. The results of this latter comparison are reproduced in the last three lines of Table III.

The validity of applying δC in this manner is not clear. Seares and Joyner introduced δC into their solution to take account of possible systematic errors in the observed colour depending on the star's magnitude and spectral type. If δC is an intrinsic property of

* *Ap. J.*, 98, 273 (Fig. 3), 1943.

TABLE III
C.I. Pole - C.I. Cape

m_{pv} Sp.	6.5	7.0	7.5	8.0	8.5	9.0
B ₉			-0.12	-0.06		
A ₀	-0.12	-0.13	-0.02	-0.06	-0.10	-0.10
A ₂		-0.08	-0.02	-0.11	-0.05	-0.01
A ₃				-0.14	-0.19	0.00
A ₅				-0.12	-0.07	-0.16
F ₀	-0.16	-0.15	-0.12	-0.13	-0.11	-0.11
F ₂		-0.17	-0.08	-0.14	-0.16	
F ₅		-0.17	-0.12	-0.17	-0.15	-0.11
F ₈			-0.16	-0.12	-0.12	+0.03
G ₀		-0.13	-0.06	-0.14	-0.14	-0.09
G ₅	-0.17	-0.19	-0.11	+0.02	0.00	0.00
K ₀	-0.24	-0.21	-0.02	+0.01	+0.05	0.00
K ₂		-0.16	-0.17	+0.10	+0.25	
K ₅				+0.13 ₁		
Ma					+0.15	
A-F	-0.14	-0.14	-0.09	-0.12	-0.12	-0.07
δC	+0.06	+0.04	0.00	-0.05	-0.06	-0.06
A-F (cor.)	-0.20	-0.18	-0.09	-0.07	-0.06	-0.01
$m_{pg}(W-C)$	-0.21	-0.24	-0.17	-0.12	-0.08	-0.15
$m_{pv}(W-C)$	-0.04	-0.01	+0.01	-0.10	-0.01	+0.09
$\Delta C.I.$	-0.17	-0.23	-0.18	-0.02	-0.07	-0.24

the stars, originating, for example, with a systematic change in colour with absolute magnitude, it should not be applied in this manner. If, on the other hand, it is a property of the observed magnitude system it should be applied.

Considering all the available data—the comparison with the Mount Wilson magnitudes for the Eros stars, the comparison with the Harvard cluster magnitudes and the comparison of the colour indices—it appears probable that the Cape photographic magnitudes need a zero-point correction of about $-0^m.13$ to make them comparable with the International photographic magnitudes. With this correction, the Cape magnitude system is probably a fair representation of the International System as far as $9^m.0$. Beyond $9^m.0$ the Cape system depends on extrapolations made by means of diffraction gratings, and the scale is likely to become increasingly unreliable with increasing magnitude.

Diffraction Gratings in Photometry.—During the past thirty years diffraction gratings have been widely used in photometry as a convenient method of establishing the scale. In the hands of Hertzprung and others who have worked with extra-focal images they seem to have yielded excellent results. Their use with focal images seems to have been less satisfactory, especially when these focal images are measured with a physical photometer like the Schilt. In particular the grating constant as determined from short exposures on bright stars seems to differ from that determined from longer exposures on fainter stars. Striking examples of this phenomena are provided by the work of Ramberg * and of Schilt †, who found for the grating he was then using a constant

* *An. Stok. Obs.*, 13, No. 9, 1941.

† *Trans. Yale U.O.*, 9, 29, 1933.

of $2^{\text{m}}.60$ from the faint stars and $2^{\text{m}}.23$ from the bright stars. Ramberg attributes this effect to a possible difference in the structure of the long- and short-exposure images, while Schilt considers it due to the failure of the diaphragm of the photometer to cover the whole of the brighter images.

Photometers like the Schilt measure the total obstruction of the image. When an image is sufficiently faint for the individual silver grains forming it to be clearly separated, the total obstruction of the image will not depend on the shape, provided, of course, that this shape can be included within the area of the analysing diaphragm. When, however, the image is denser and the individual silver grains forming it begin to overlap, the arrangement of the silver grains, *i.e.* the shape of the image, begins to be important, since the less the silver grains overlap, the greater the obstruction power of the image. In the case of images which are completely "burnt out", it is the size of the image that is measured by the photometer, so that its shape is all-important. Consider now the relative behaviour as the exposure varies of two images formed by the same amount of light, the first a grating side image of one star, the second the central image of another fainter star. Now, however good the grating, the side image is necessarily elongated when compared with the central image, unless they are both formed by monochromatic light. This will not matter at low photographic densities since the photometer measures the total area of the exposed silver grains forming the image, irrespective of their arrangement, but at high photographic densities the size of the image is important, and the grating image which is the bigger will appear to have been formed by a brighter star. The grating constant will therefore appear to be smaller for bright stars than for faint. The dependence of the elongation of the side image on the colour of the star will explain the change of grating constant with colour.

The effect of the size of the analysing diaphragm of the photometer on the observed grating constant can be understood if one considers the structure of the normal in-focus image. This consists of a core that is heavily exposed surrounded by a small area which is lightly exposed. This lightly exposed area is naturally larger for a grating side image than for a central image. The core of the image has a minimum size which depends on the conditions of observation, but there is no maximum size for, as the exposure is increased, the core first of all gets "burnt out" and then starts to spread. If the analysing diaphragm is only about the minimum size of the image core, the photometer will measure the densities of the images without regard to their shapes (it is almost the case of extra-focal images), but if the analysing diaphragm is large enough to take in not only the core but also all its surroundings, the photometer will take full account of the extra area over which the grating image is spread. In the first case we can expect the grating constant to have its maximum value, which may be larger than its theoretical value, since the density of the grating image is likely to be less than that of the corresponding central image which is not spread out over quite so large an area. In the second case, of the very large diaphragm, the value of the grating constant will be a minimum. Analysing diaphragms with areas between these two extremes can be expected to give an intermediate value for the grating constant. For all the larger diaphragms one can expect the grating constant to increase with decreasing density of the images.

Had we been aware of these variations in the grating constant when we started our photometric programme, we should never have attempted to use diffraction gratings. We quickly found the variation of grating constant with the size of the analysing diaphragm, but we assumed that the measured difference between side and central image was constant for any given plate. We attempted to test this assumption by measuring grating plates of the Pleiades taken with different exposure times. The results, though slightly complicated by colour effects, seemed to indicate that this assumption was justified until the side images became so faint that they were barely measurable. The apparent grating constant then appeared to increase rapidly. In routine work we have always avoided the measurement of such faint images.

The neglect of the increase in the grating constant with decreasing density and the adoption of the value of the constant found from the brighter stars will mean that faint stars have been measured as brighter than they really are, *i.e.* the Cape magnitudes will need a positive correction for the fainter stars. This is also indicated by the Mount Wilson magnitudes for the Eros comparison stars, but I shall be surprised if the corrections to the Cape magnitudes prove to be quite as large as the Mount Wilson magnitudes imply.

Concluding Remarks.—One fact stands out clearly from this investigation. Before the Cape magnitudes can be reduced satisfactorily to the International System, there must be available for observation from the Southern Hemisphere a selection of stars whose magnitudes are well determined on that system.

The qualification "well determined" needs a certain amount of amplification. The International System is at present defined by the North Polar Sequence. For the stars between 6.0 and 11.0, with which we are chiefly concerned, that sequence is probably inadequate and is likely to be replaced by the Mount Wilson Polar Catalogue. This catalogue sets a new standard of accuracy for photographic photometry, a standard which all future photometry to be judged "satisfactory" must at least achieve, if not surpass. That this standard is worth achieving is clearly shown by Seares and Joyner's * masterly discussion of their catalogue. In particular, questions involving colour excess, the extent of the absorbing cloud in the neighbourhood of the Sun, etc., are not likely to be solved satisfactorily until we have a network of well-determined magnitudes covering the sky from pole to pole. When one considers the fundamental nature of stellar magnitudes—few, if any, astrophysical investigations are completely independent of a knowledge of the magnitude—the chaotic state of the existing magnitude systems is little short of scandalous, especially when it is compared with the high degree of accuracy attained in the differential photometry of variable stars. The unsatisfactory nature of the present position is fully realised by the Photometry Commission of the International Astronomical Union.† At its last meeting a number of alternative proposals were discussed and two sub-committees were appointed. Owing to the War, the work of these committees seems to be in abeyance.‡

As Mrs. Payne-Gaposchkin § says in her excellent review of the Mount Wilson Catalogue, "The requirements of photometric standards, though simple to state, are difficult to meet. Only those who have had practical experience in photographic photometry are aware of the severe requirements by which the three essentials (accuracy of scale, determination of zero-point and knowledge of colour coefficient) are circumscribed and may be attained. The difficulty of the problem may be measured by the rarity with which these requirements are met".

In the past the emphasis has been on the building up of standard sequences according to some definition rather than on the establishment of a homogeneous system and its subsequent critical examination. The new Mount Wilson Catalogue is probably both good enough and extensive enough to be used as the basis of such a homogeneous system. The next step is to transfer this system to a number of areas in lower declinations. That this is necessary is clear from the fact that for many observatories the pole is too low in the sky for satisfactory routine photometry. Moreover, any particular area can be compared with the pole at two times only—when its altitude is that of the pole. There is also the instrumental difficulty of ensuring that the polar images are strictly comparable as regards form with those being compared with them. The advantages of standard sequences which pass close to the observer's zenith are obvious. Comparisons can be carried out at smaller zenith distances, and, if there is a choice of sequences, at different zenith distances, enabling systematic errors to be more easily detected. (The effect of selective atmospheric extinction, for example, which was detected only after an elaborate analysis of the Polar Catalogue ||, appeared quite clearly in the intercomparison of the

* *Ap. J.*, 98, 244, 261, 302, 1943.

† *Ap. J.*, 97, 78, 1943.

|| *Ap. J.*, 98, 312, 1943.

† *Trans. I.A.U.*, 6, 406, 1939.

§ *Ap. J.*, 97, 78, 1943.

E regions.*) Moreover, the extinction changes so slowly for zenith distances up to about 25° that multiple exposures for comparisons can be safely used.

The number of standard regions need not be very large, as it is clearly better to have a few regions with well-determined magnitudes than many regions with poorly determined ones. About twenty would probably be sufficient. Of these, about eight should be at $+30^\circ$ or $+45^\circ$ for general use in the Northern Hemisphere, four on or south of the Equator for extending the system southwards, and another eight or so at -30° or -45° for general use in the Southern Hemisphere. The magnitudes of all the stars within a certain area of each region should first be obtained on the one homogeneous system by intercomparison of the various regions with each other and with the polar area. A number of stars in each region could then be chosen for intensive investigation with as great a variety of photometric methods as possible. The object of this intensive investigation would be to elucidate the scale and colour characteristics of the adopted magnitude system.

The accuracy of the Mount Wilson Polar Catalogue can be only partly ascribed to the quality of the apparatus with which the plates on which it is based were obtained and measured. It mainly results from the great care with which these measures were reduced and discussed. Outstanding in this discussion is the recognition of the fact that field corrections change from plate to plate and depend not only on the position on the plate but also on the colour of the star and the size of its image. This makes it essential for photographic and photovisual magnitudes to be determined together. A knowledge of the colour is also necessary to enable the observed system of magnitudes to be reduced to the standard one, for, however hard we try, we are unlikely to obtain equipment which will give magnitudes that are exactly on the standard system. It must be emphasised that, for accurate photometry, a magnitude, unassociated with a colour, means very little, if anything, since what it measures is a combination of at least two independent quantities, the total radiation emitted and the spectral distribution. It seems probable that magnitudes depending on two ranges of colour can be reduced to a standard system for all normal stars. The reductions may not be linear, but they should be functions of the observed magnitudes expressible in tabular form. The colour ranges in normal use are adequate, but there seems no valid reason why the photovisual region should not be extended more to the red or the photographic one to the violet.

The size of the area to be investigated in each standard region will depend on the equipment most likely to be used for routine photometry. The plates on which the Polar Catalogue is based were taken with Ross lenses and measured in a physical photometer. Four component lenses of the Ross type give measurable images over large fields. For the purpose of the Polar Catalogue it was desirable to use fields as large as ten degrees in diameter to include as many standard stars as possible, but for ordinary routine photometry it would appear more economical in total time and effort to confine the measures to the central part of the field (some four to five degrees square) and to the two- or three-magnitude range for which the curves reducing the plate measures to magnitudes are linear. For with these restrictions the distance corrections are likely to prove small and relatively constant, provided the plates are obtained under reasonably uniform conditions.

In this case only an area of about five degrees square need be investigated in each region, although it might be convenient to extend the equatorial regions to an area of fifteen degrees (or more) square. This would strengthen the link between the Northern and Southern hemispheres and provide areas from which the field correction of any telescope could be determined. Areas of five degrees square will not, in general, provide an adequate number of stars brighter than the seventh magnitude. This may not be a disadvantage, for it is probable that the magnitudes of all such stars should be determined individually.

The programme outlined above is likely to prove laborious though not necessarily

* *M.N.*, 103, 302, 1943.

difficult. The Polar Catalogue seems to have taken two or three people about nine years to complete, but many of the difficulties encountered in its preparation will not have to be faced again. What is clear is that little progress can be made in accurate photometry until some such work has been done. Nor does the amount of work appear excessive in proportion to the value of the result to be achieved, if one compares it with the labour that has to be expended to prepare equivalent catalogues of star positions, radial velocities or trigonometrical parallaxes.

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THE THEORY OF THE FOUCAULT TEST

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Summary

A diffraction theory for the Foucault knife-edge test is given, a closed expression being obtained for the variation of light-intensity over a mirror with arbitrary error when it is tested with a knife-edge. The geometrical explanation of the test is derived as the limit when $\lambda \rightarrow 0$, and examples are given of several commonly occurring errors. In particular, it is shown that an edge turned by $\frac{1}{2}n\lambda$ will give rise to n well-defined fringes.

1. *Introduction.*—The Foucault knife-edge, well known to astronomers, is usually explained in terms of ray optics, and most of its observed features can be accounted for in this way satisfactorily enough; but a really adequate theory, dealing, of course, with retardations of the order of a wave-length, must necessarily be on a wave-theory basis. In 1934 Prof. F. Zernike * published such a theory, in which he showed how the intensity-distribution over a mirror with arbitrary error could be calculated when the mirror was examined under the knife-edge in the usual way. Zernike, however, was chiefly concerned with finding the limit of sensitivity of the test; his analysis is limited to retardations small compared with $\lambda/2\pi$, and so, as far as the working optician is concerned, is applicable only to mirrors which are already very nearly perfect.

In the present paper we discard this restriction, and in section 2 derive a closed expression for the variation of intensity over a mirror with arbitrary error, not necessarily small compared with λ , when it is tested with a knife-edge. In section 3 we examine the geometrical case $\lambda \rightarrow 0$, showing in particular how the intensity then depends on the differential of the error and not on the error itself. In section 4 we explain the well-known phenomenon of the appearance of fringes on a mirror with a turned edge, and in section 5 compute intensity-curves for mirrors with central and zonal errors. To avoid mathematical difficulties the analysis has been restricted to two dimensions throughout.

Once again I must express my indebtedness to Dr. Linfoot for suggesting the problem and for his continual encouragement and criticism during its investigation. I must also thank the University of Bristol for the award of the Michael Hiatt Baker Scholarship, during the tenure of which a large part of the work described here was carried out.

2. *The Theory of the Foucault Test.*—In Fig. 1 SQP represents a wave-front of arbitrary shape, converging approximately to an axial point F. We can suppose such a wave-front to have been produced by reflection in a mirror. KF is the plane in which the knife-edge is introduced, and the observing eye or telescope, assumed focused on the mirror surface, is directed along TF at an angle ϕ with the axis. We denote the departure of the wave-front from a circle of centre F and radius f by a retardation function $R(\theta)$, with such sign that the polar equation of SQP, referred to F as pole and FP as axis, is

$$FQ = f - R(\theta).$$

Thus if $R(0) = 0$, $f = FP$.

* *Physica*, 1, 689, 1934.

We note that the presence in R of a term linear in θ (R being otherwise symmetrical) is tantamount to a rotation of the axis PF about P, or to a displacement of the edge of the knife-edge from F. A term in θ^2 means that the knife-edge is not at the focus of the wave. Conversely we may simulate such off-axis and out-of-focus effects by introducing into R terms depending on θ and θ^2 respectively.

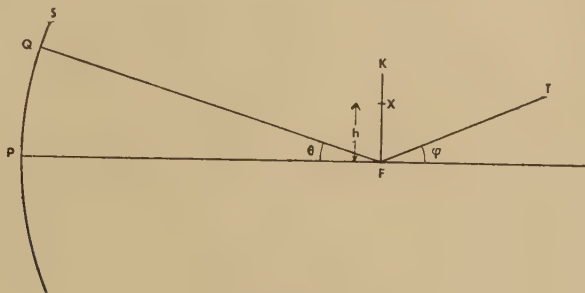


FIG. 1.

Consider an element of the wave adjacent to a point Q which is at angular distance from P of $\widehat{PFQ} = \theta$. The complex disturbance due to that element at X, a point in the knife-edge plane distant h from the axis, is $A \exp \frac{2\pi i}{\lambda}(ct - QX)$, where c is the velocity of light and A an amplitude factor which we suppose constant over the wave. Assuming $R/f, h/f, \theta \ll 1$ we have

$$QX = f - h\theta - R,$$

and if we choose the unit of length so that $\lambda = 2\pi$, the disturbance at X is

$$A \exp i(ct - f + h\theta + R).$$

Set $\theta = a\xi$ and $u = ah$, where $\pm a$ are the angles defining the limits of the wave, so that $a = \widehat{PFS}$. Following Zernike, we expand $\exp iR(a\xi)$ in Legendre functions, the coefficients C_n in the expansion

$$\exp iR(a\xi) = \sum_{n=0}^{\infty} C_n P_n(\xi) \quad (2.1)$$

being given by

$$C_n = \frac{2n+1}{2} \int_{-1}^1 P_n(\xi) \cdot \exp iR(a\xi) \cdot d\xi.$$

Then the disturbance at X due to the element at Q is

$$A \exp i(ct - f + u\xi) \cdot \sum_{n=0}^{\infty} C_n P_n(\xi).$$

To find the disturbance $X(u)$ at X due to the whole wave we integrate this expression over the wave-front, so obtaining

$$X(u) = \int_{-1}^1 \sum C_n P_n(\xi) \cdot e^{iu\xi} d\xi. \quad (2.2)$$

We have omitted the factor $A \exp i(ct - f)$, as it is constant for any particular wave. Using Gegenbauer's well-known result (Watson, *Bessel Functions*, p. 50) that

(2.2) becomes

$$X(u) = \sqrt{\frac{2\pi}{u}} \sum_{n=0}^{\infty} C_n i^n \mathcal{Y}_{n+\frac{1}{2}}(u). \quad (2.3)$$

For a perfect mirror all the C 's except C_0 are zero, and we recover the well-known expression

$$X(u) = \frac{2 \sin u}{u}.$$

To find the disturbance $D(\phi/a)$ in the direction ϕ we multiply $X(u)$ by the approximate phase factor $e^{-ih\phi}$ and integrate with respect to h over the part of the knife-edge plane KF unobstructed by the knife-edge itself or by the aperture of the observing system. In our units the latter quantity is of the order 10^5 and may nearly always be taken to be infinite. Assigning as limits zero and infinity, and setting $\phi = \alpha x$, so that $h\phi$ becomes xu , we have to evaluate

$$\begin{aligned} D(\phi/a) = D(x) &= \int_0^{\infty} e^{-ixu} X(u) du \\ &= \sum_{n=0}^{\infty} C_n i^n \int_0^{\infty} e^{-ixu} \mathcal{Y}_{n+\frac{1}{2}}(u) \sqrt{\frac{2\pi}{u}} du. \end{aligned} \quad (2.4)$$

This depends on the integral

$$\begin{aligned} I_n &= \int_0^{\infty} e^{ixu} \mathcal{Y}_{n+\frac{1}{2}}(u) \sqrt{\frac{2\pi}{u}} du = i^n \{ \pi P_n(x) + 2i Q_n(x) \}, & x^2 < 1 \\ &= 2i^{n+1} Q_n(x), & x^2 > 1 \end{aligned} \quad (2.5)$$

which for $x^2 > 1$ was given by Jeffery *, and for $x^2 < 1$ by Zernike (*loc. cit.*).

Combining (2.4) and (2.5), we have for $x^2 < 1$,

$$D(x) = \sum_{n=0}^{\infty} C_n \{ \pi P_n(x) - 2i Q_n(x) \}, \quad (2.6)$$

and for $x^2 > 1$,

$$D(x) = -2i \sum_{n=0}^{\infty} C_n Q_n(x). \quad (2.7)$$

To evaluate the latter sum we observe that the result †

$$2Q_n(x) = \int_{-1}^1 \frac{P_n(y) dy}{y-x},$$

which for real x holds as it stands only for $x^2 > 1$, will, if we agree now, and in the rest of the paper, to take the Cauchy principal value of all integrals with infinities in the integrand, hold also for $x^2 < 1$. Substituting in (2.6) and (2.7), we have finally, for the disturbance $D(x)$ in the direction defined by x ,

$$D(x) = \pi e^{iR(x)} + i \int_{-1}^1 \frac{e^{iR(y)} dy}{y-x}, \quad x^2 < 1 \quad (2.8)$$

$$D(x) = i \int_{-1}^1 \frac{e^{iR(y)} dy}{y-x}, \quad x^2 > 1. \quad (2.9)$$

* *Proc. Lond. Math. Soc.* (2), 16, 138, 1917.

† Whittaker and Watson, *Modern Analysis*, 3rd edn., p. 320, 1920.

The observed intensity is $|D(x)|^2$. These expressions are valid subject only to the condition $R \ll f$.

For a perfect mirror with the knife-edge at its centre of curvature $R=0$ everywhere, and

$$\begin{aligned} D(x) &= \pi + i \ln \left| \frac{1-x}{1+x} \right|, & x^2 < 1 \\ &= i \ln \left| \frac{1-x}{1+x} \right|, & x^2 > 1. \end{aligned}$$

The intensity inside the edge is

$$|D(x)|^2 = \pi^2 + \ln^2 \left| \frac{1-x}{1+x} \right|. \quad (2.10)$$

Outside the edge it is

$$|D(x)|^2 = \ln^2 \left| \frac{1-x}{1+x} \right|. \quad (2.11)$$

These results were first given by Rayleigh.* It will be noticed that they lead to a logarithmic infinity in the intensity when $x=1$, *i.e.* at the edge of the mirror, corresponding to the brilliant thread of light at the edge well known in practice. Rayleigh showed how the difficulty introduced by this infinite value could be avoided by taking into account the finite aperture of the observing system, *i.e.* by assigning a suitable upper limit to the integral in (2.4).

We obtain Zernike's result from (2.8) by assuming that R is small enough for $e^{iR(x)}$ to be replaced by $1+iR(x)$. We can then write (2.8) in the form

$$e^{-iR(x)}D(x) = \pi + i \int_{-1}^1 \exp i\{R(y) - R(x)\} \frac{dy}{y-x},$$

from which, expanding and neglecting squares of R , we have for the intensity

$$|D(x)|^2 = \pi^2 + \ln^2 \left| \frac{1-x}{1+x} \right| - 2\pi \int_{-1}^1 \frac{R(y) - R(x)}{y-x} dy,$$

which can be shown to be equivalent to equation (18) of Zernike's paper when a mistake in sign in the latter has been corrected.

3. *The Geometrical Case.*—In this section we show how the usual explanation of the knife-edge test † follows from the diffraction theory by considering the limit of (2.8) as $\lambda \rightarrow 0$. λ does not enter (2.8) explicitly; it will be remembered, however, that we chose $\lambda/2\pi$ as unit of length. This choice is equivalent to making R a phase instead of a linear retardation; then as $\lambda \rightarrow 0$, the phase-retardation R becomes great (the linear retardation remaining constant), and we are led to consider the limit of (2.8) as $R \rightarrow \infty$. No attempt is made at mathematical rigour in what follows.

We shall first establish a result concerning the integral

$$\int_b^a e^{iR(y)} \frac{dy}{y-x}, \quad a < x < b,$$

which will find a good deal of application in the rest of the paper. Write

$$\int_b^a e^{iR(y)} \frac{dy}{y-x} = e^{iR(x)} \int_b^a \exp i\{R(y) - R(x)\} \frac{dy}{y-x}. \quad (3.1)$$

The chief contribution to the integral will come from the region of y in the immediate vicinity of x . Therefore in expanding $R(y)$ as a Taylor series about x , we may with some

* *Phil. Mag.*, **33**, 161, 1917; *Collected Papers*, **6**, 455.

† See, for example, Gaviola, *Amateur Telescope Making, Advanced*, Munn & Co., p. 76, 1937.

confidence neglect R'' and higher coefficients. Performing this expansion, and writing $y - x = t$, we have

$$\int_b^a \exp i\{R(y) - R(x)\} \frac{dy}{y-x} \simeq \int_{b-x}^{a-x} e^{iR't} \frac{dt}{t} = \left(\int_{b-x}^{-\infty} + \int_{-\infty}^{\infty} + \int_{\infty}^{a-x} \right) e^{iR't} \frac{dt}{t}. \quad (3.2)$$

Considering first the middle integral, it is well known that

$$\int_{-\infty}^{\infty} \frac{\sin at}{t} dt = \begin{cases} +\pi, & \text{if } a > 0 \\ 0 & a = 0 \\ -\pi & a < 0. \end{cases}$$

$\int_{-\infty}^{\infty} \frac{\cos at}{t} dt$ vanishes because the integrand is odd. We may integrate the other two integrals by parts, as their arguments are always finite. Then if x is not too near a or b , (3.2) becomes

$$\int_{b-x}^{a-x} e^{iR't} \frac{dt}{t} = \pm \pi - \frac{ie^{i(a-x)R'}}{(a-x)R'} + \frac{ie^{i(b-x)R'}}{(b-x)R'} + O\left(\frac{1}{R'^2}\right),$$

the upper sign holding for R' positive, the lower for R' negative. Substituting this in (3.1), we have finally

$$\int_b^a e^{iR(y)} \frac{dy}{y-x} = \pm i\pi e^{iR(x)} - \frac{ie^{iR(a)}}{(a-x)R'(x)} + \frac{ie^{iR(b)}}{(b-x)R'(x)} + \dots,$$

the upper sign holding for R' positive. We have used

$$R(a) \simeq R(x) + (a-x)R'(x).$$

Returning now to the limit of (2.8), we substitute (3.3) in (2.8) with $a = 1$, $b = -1$, and obtain

$$D(x) = \pi e^{iR(x)} \mp \pi e^{iR(x)} + \frac{e^{iR(1)}}{(1-x)R'} + \frac{e^{iR(-1)}}{(1+x)R'} + \dots,$$

the upper sign holding for R' positive, the lower for R' negative. When R' is positive, the intensity in the direction x , equal to $|D(x)|^2$, is of order $1/R'^2$, *i.e.* very small. When R' is negative it is $4\pi^2 + O(1/R')$; thus the mirror is bright or dark, depending on the slope of the error. This dependence of the observed quantity, the intensity, on the differential of the error and not on the error itself, is a leading characteristic of the Foucault test.

To show what happens as we bring in the knife-edge from the edge of the field, we replace R by $R + kx$, and hence R' by $R' + k$. k is a constant depending on the distance of the knife-edge from the axis (if this distance is d , k is $\pi d/\lambda$ (focal ratio)—see the beginning of section 2). Initially k is large and negative, so that $R' + k$ is negative and the whole of the mirror is bright. As we advance the knife-edge k increases (algebraically), and with it $R' + k$, until for the part of the mirror with largest R' , $R' + k$ becomes positive and the corresponding area suddenly darkens. As the knife-edge continues to advance, k passes through zero and becomes positive, $R' + k$ becomes positive for smaller and smaller values of R' , and the corresponding parts of the mirror darken successively, until for k sufficiently large the whole mirror is dark.

In practice, of course, the character of the intensity pattern is far less abrupt, the alternations of light and shade becoming very delicate as the figure of the mirror improves. In the rest of the paper we shall work out intensity curves for various types of commonly occurring errors.

4. *Intensities for a Turned Edge.*—The first particular case we shall consider is that

of a turned edge. We suppose the mirror free from error over the region for which $-e < x < e$, $1-e$ being small. A symmetrical turned edge of $n\lambda$ is then described by a retardation function $R(x)$ which

- (a) is even;
- (b) is zero for $-e \leq x \leq e$;
- (c) decreases from zero to $-4n\pi$ as x increases from e to 1 . The factor $-4n\pi$ arises because the error on a wave reflected by a mirror is twice that on the mirror itself, and is negative because the edge is turned *down*.

Suppose that $e=0.9$ and $n=1$, i.e. that we have a turned edge of one λ over the outer tenth of the mirror. Then as x increases from 0.9 to 1.0 , R decreases from 0 to -4π , so that, even for this by no means extreme example, the average value of R' is -40π , which is greater than a hundred. We may therefore expect that an approximation on the lines of section 3, using this fact that R' is large, will be a good one.

With $R'=0$ for $-e < x < e$, the fundamental equation (2.9) becomes

$$D(x) = \pi e^{iR(x)} + i \int_{-e}^e \frac{dy}{y-x} + i \left(\int_{-1}^{-e} + \int_e^1 \right) \frac{e^{iR(y)}}{y-x} dy. \quad (4.1)$$

We evaluate the last integral on the right-hand side by putting $a=1$, $b=e$, in (3.3), when for $1 < x < e$, we obtain

$$i \int_e^1 \frac{e^{iR(y)}}{y-x} dy = \mp \pi e^{iR(x)} + \frac{e^{iR(1)}}{(1-x)R'(x)} - \frac{e^{iR(e)}}{(e-x)R'(x)},$$

the upper sign holding for R' positive. We may show similarly that the integral from -1 to $-e$ is negligible. Substituting for these integrals in (4.1), and neglecting in the meantime terms in $1/R'$, we have

$$\left. \begin{aligned} D(x) &= -i \ln \frac{x+e}{x-e}, & R' \text{ positive} \\ &= 2\pi e^{iR(x)} - i \ln \frac{x+e}{x-e}, & R' \text{ negative} \end{aligned} \right\} \quad (4.2)$$

Thus for R' positive, i.e. over the "dark" edge, the intensity is $\ln^2 \frac{x+e}{x-e}$. Over the bright edge it is

$$4\pi^2 - 4\pi \ln \left(\frac{x+e}{x-e} \right) \sin R + \ln^2 \frac{x+e}{x-e}. \quad (4.3)$$

The value of $\ln \frac{x+e}{x-e}$ over the range in x in which we are interested is roughly 3.3. To this approximation the intensity is about $50 - 40 \sin R$, and we will have intensity maxima of about 90 at $R = -\pi/2, -5\pi/2, \dots$, and minima of about 10 at $R = -3\pi/2, -7\pi/2, \dots$, i.e. associated with a turned edge of n fringes will be an intensity pattern with n maxima separated by $(n-1)$ minima. These fringes are well known in practice and are easily seen when the test is carried out with a small pinhole.

It is of interest to compare intensity patterns given by the asymptotic formula (4.3) with those calculated by more exact means from (4.1). To this end we choose for R the form

$$\begin{cases} R(x) = -8\pi(10x-9)^r, & x > 0.9; \\ R(x) = 0, & 0 < x < 0.9; \\ R(-x) = R(x) \end{cases} \quad (4.4)$$

corresponding to a mirror with a turned edge of one wave-length, and compute intensity curves for the cases $r=1, 2$ and 3 . Generally speaking, the higher r is the better the

approximation to practice. The linear case, with $r=1$, has the advantage, however, that the integrals on the right of (4.1) reduce to the Ci and Si integrals tabulated in Jahnke-Emde and elsewhere. For $r=2$ and $r=3$ ("parabolic" and "cubic" edges), they had to be evaluated by Simpson's rule, a rather laborious process in this case, as each point on the intensity curve required two numerical integrations. Intensities on the dark edge were found most simply by writing $-R$ for R in (4.1). This follows by observing that if in (2.9) we write successively $-R$ for R and $-x$ for x , $D(-R, x)$ is the complex conjugate of $D(R, -x)$, so that

$$|D(-R, x)|^2 = |D(R, -x)|^2.$$

Physically this means that two mirrors whose errors would together add up to zero have intensity curves differing only in that each is a right-to-left transposition (reflection in the optical axis) of the other.

In Table I we compare bright-edge intensities computed in the way just described (I_{exact}) with those given by the asymptotic formula (4.3) ($I_{\sim}$). We sharpened the latter by the inclusion of the $1/R'$ term, which simplifies in this case because

$$e^{iR(0.9)} = e^{iR(1.0)} = 1.$$

If also we use the value for R' derived from (4.4), we find after a little reduction,

$$I_{\sim} = 4\pi^2 - 4\pi \sin R \ln \frac{x+e}{x-e} + \ln^2 \frac{x+e}{x-e} - \frac{\cos R}{r(10-10x)(10x-9)^r}. \quad (4.5)$$

TABLE I
Intensity Variation over a Turned Edge

x	Linear			Parabolic			Cubic			Perfect Mirror
	R	I_{exact}	$I_{\sim}$	R	I_{exact}	$I_{\sim}$	R	I_{exact}	$I_{\sim}$	
0.90	0.00	57.7	...	0.00	35.0	...	0.00	28.7	...	18.54
91	10	120.9	125.2	01	49.0	19.6	00	...	...	19.20
92	20	96.2	98.2	04	75.0	74.5	01	44.6	13.7	19.97
93	30	29.7	29.9	09	103.3	99.7	03	...	...	20.87
94	40	7.3	7.1	16	108.0	99.9	06	90.1	82.8	22.02
95	50	48.8	48.5	25	62.6	56.5	12	110.8	97.9	23.29
96	60	91.5	91.0	36	9.1	9.5	22	89.0	72.7	25.02
965	65	92.8	92.2	42	11.8	14.0	27	48.4	41.2	26.09
97	70	78.8	78.4	49	40.6	41.7	34	11.6	13.6	27.38
975	75	55.2	55.2	56	78.3	75.9	42	10.7	14.4	28.96
98	80	30.6	31.2	64	94.3	89.2	51	52.8	52.2	30.99
985	85	13.4	14.5	72	70.9	66.6	61	96.7	87.2	33.74
99	90	8.9	8.9	81	28.7	27.1	73	71.2	63.1	37.89
995	95	17.8	9.3	90	7.9	9.3	86	11.3	13.4	45.74
1.000	1.00	...	...	1.00	...	...	1.00	...	...	...

Table I also includes intensities for a perfect mirror, computed from (2.10). It turns out that for the parabolic and cubic cases the approximation is not much improved by the addition of the $1/R'$ term. However, it seems that in any case the approximation is a good one, better perhaps than might have been expected from some of the assumptions in the analysis. Another feature of Table I, confirming in a general way the correctness of (4.5), is the extent to which I is independent of the exact form of R . This is well

brought out in Fig. 2, in which we have plotted I as a function of R (not of x) in each of the three cases. It will be seen that for x greater than about 0.93, the points lie nearly on the same curve, irrespective of whether they relate to a linear, parabolic, or cubic edge.

The intensity for a parabolic edge is plotted against x on the left-hand side of Fig. 3. The sharp contrast of the fringes is well shown. On the right of the same figure is shown the intensity curve for the dark edge, which has hitherto not been considered.

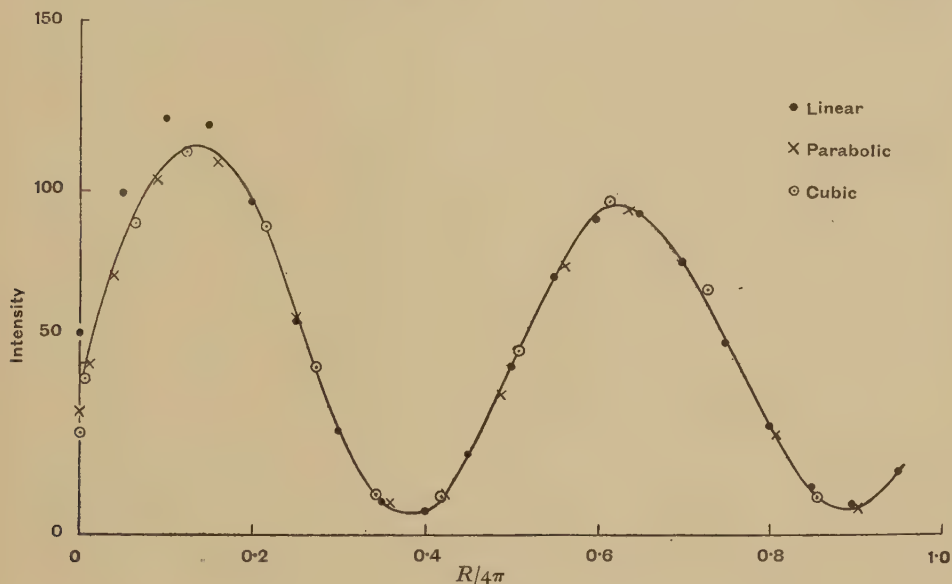


FIG. 2.

It is found that intensities over these edges are well represented by the asymptotic expression $\ln^2 \frac{x+e}{x-e}$ which follows (4.2). The curves, of which the case shown is typical, are more or less uniform and of not much interest.

5. *Other Examples.*—We have not had time to consider any other form of error in detail, but as two further illustrations of the theory have worked out intensity curves for mirrors with a hollow centre and with a hollow zone. The method has been as before, to choose a form of R which gives a reasonable representation of what is observed in practice, then to evaluate the necessary integrals numerically. It should be pointed out that as the theory is only two-dimensional, intensity curves computed in this way cannot be assumed *a priori* to be quantitatively true unless only a diametral strip of the mirror is exposed for test. It is well known in practice, however, that such screening has but little effect on the intensity distribution, and, in any case, the functional representation of the error is itself only approximate.

For the hollow centre we took

$$R = -4\pi(1 - 25x^2)^2, \quad \begin{array}{l} x^2 < \frac{1}{25} \\ = 0 \quad \quad \quad x^2 > \frac{1}{25}. \end{array}$$

The width of the depression was thus one-fifth of the diameter of the mirror, and its maximum depth (one-half of that of the returning wave) one wave-length. For the zone we took R even, and zero except when $0.7 > x > 0.6$, when

$$R = -2\pi\{1 - (20x - 13)^2\}^2.$$

The zone was thus a twentieth of the diameter wide and half a wave-length, or one fringe deep.

The computations do not call for comment. The curves obtained are plotted in Fig. 3, together with that for a parabolic turned edge. The dotted line is the curve for a perfect mirror, computed from (2.10), and the full line beneath the intensity curve is the profile of the mirror. In plotting all three curves on the one figure we are assuming that the influence of any one error is negligible at an appreciable distance from the zone containing the error. This is confirmed by computations and is not difficult to demonstrate, at any rate for R' large, by an approximation on the lines of section 3.

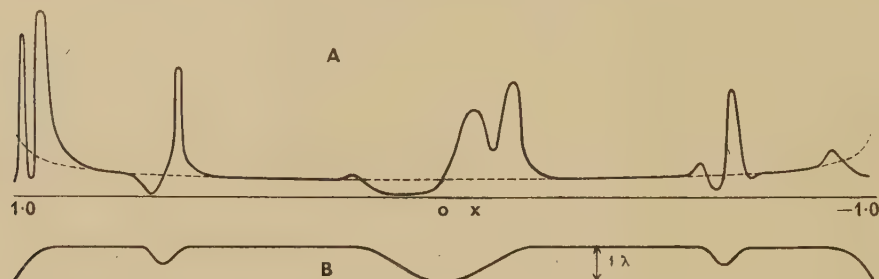


FIG. 3.—Intensity A over a mirror with profile B when tested with a knife-edge entering from the right. The broken curve is the intensity for an error-free mirror.

Turning to Fig. 3, an unexpected feature was the appearance of the fringe structure over the brighter part of the intensity curve for the hollow centre. The minimum is not so marked as with a turned edge, but should be detectable easily enough. There appears to be no record of such an observation having been made. The sensitivity of the test is well displayed by the rapid and wide variations in intensity over the one-fringe zone. This curve agrees well with the geometrical interpretation of the test, but here, too, fringes appear as soon as the depth of the zone is increased beyond $\frac{3}{4}\lambda$, i.e. $1\frac{1}{2}$ fringes.

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A POSSIBLE SOURCE OF ERROR IN THE PHOTOGRAPHIC PHOTOMETRY OF THE SOLAR CORONA *

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Summary

If a photographic image of an opaque circular mask surrounded by an area of uniform illumination is produced by contact printing and subsequent development a radial density gradient outside the masked area is obtained. This gradient may extend up to 5 centimetres from the mask-edge, and is not to be confused with the usual Eberhard edge-effect. It is similar in direction, but smaller in order of magnitude when compared with the density gradient exhibited in an eclipse photograph of the Moon's image and solar corona.

The effect may be ascribed to a non-uniform distribution of the products of development. When the mask-image is entirely symmetrical with respect to the boundaries of the plate, and no preferential direction of rocking is employed during development, the radial gradient which results will not alter appreciably with position angle. Any departure from these conditions will introduce a second-order effect and produce an asymmetry of the density gradient.

A quantitative estimate of the errors likely to occur in photographic photometry of this type is made, and applied to the specific problem of the photometry of the inner corona from an uncalibrated eclipse photograph taken in 1905.

Introduction.—The purpose of the present paper is to direct attention to the possibility of significant photometric errors arising from the influence of the "Nachbar-Effekt" † on photographs of the solar corona. For it is not impossible that inherent effects of development may so modify the photographic record of the eclipsed Sun and sky background that, aside from any consideration of the exposure to the solar corona, a spurious density gradient may result which will be similar in direction, but smaller in order of magnitude, when compared with the true density distribution within the coronal image.

For example, let it be supposed that, in the absence of a corona, this image is surrounded by an area of density in the photograph which represents a uniformly illuminated sky background (light leakage from the solar limb is assumed to be negligible). The density pattern will then be a simple one—a circular area of low density (image of Moon), surrounded by an area of density (sky background) which may be expected to be uniform. The juxtaposition of these two densities of differing magnitude and extent will affect, however, local progress of the developing latent image. Even with the moderate degree of continuous agitation which is associated with the

* Communication No. H1003 from the Kodak Research Laboratories.

† For detailed descriptions, see:

G. Eberhard, *Publ. Astrophys. Obs., Potsdam*, 84, 1926.

N. Walenkov, *Zeitschr. f. wiss. Phot.*, 27, 236, 1929.

J. Junkes, *Ibid.*, 36, 217, 1937.

normal technique of rocked-dish development, a volume of comparatively fresh developer will be trapped within the emulsion in the area of the Moon's image and, owing to the low final density of the latter, the concentration of restrainer (liberated bromide) will be low. In consequence, a gradual diffusion of energetic developer will ensue, and this radial migration into the contiguous area of sky image will tend to augment the density of the latter relative to those areas which are more remote. A differential rate of development of this nature over the sky image may well establish a negative density gradient outwards from the solar centre. Thus, the density distribution which supposedly represents the uniformly bright sky background may simulate in its general features the actual distribution which is to be expected from an exposure to the corona.

Further, if the image of the eclipsed Sun is symmetrical with respect to the edges of the plate, the negative density gradient set up by the developer action will be the same for all position angles provided that random rocking of the dish is maintained throughout development. If this is not the case, or if any asymmetry exists as, for example, when using a rectangular dish in which to develop a square plate, a second-order effect will be introduced which will produce a variation of the radial density gradient with position angle. It is probable that, in the majority of instances, both first- and second-order effects will be present, the magnitude of the latter being usually the smaller. On account of the rapid diminution of gradient over the area of the negative bearing an image of the outer regions of the corona it seems unlikely that any photometry of the outer corona will be influenced by the development effect.

Recently, H. A. Brück has published * data for the distribution of intensity within the inner corona which have been obtained from a plate photographed by H. F. Newall during the solar eclipse of 1905 August 30.† A perusal of this paper suggested the desirability of an experimental investigation of the likely magnitude of any errors which might result from development effects of the Nachbar type by photographing an artificial "eclipsed Sun" under controlled conditions in the laboratory.

Experimental.—The Moon's image was simulated by an opaque disc of black paper, 38 mm. diameter ‡, mounted on a clear glass plate, $6\frac{1}{2}$ inches by $4\frac{3}{4}$ inches. In order to examine the influence of the geometry of the image, especially with reference to the edges of the plate, the paper mask was located asymmetrically. The mask image and its surround were printed down, by contact, on to two different process brands § of negative material. Exposures were made by uniformly "flashing" the plates with white light. A pair of plates of each brand was exposed to yield two different average density levels in the region surrounding the mask-image. Each plate was processed in an M.Q. developer. Rocked-dish development for $3\frac{1}{2}$ minutes with continuous agitation at 68° F. was given, and development was full.

Each negative was microphotometered along two axes respectively parallel to, and at right angles to the longer edge of the plate. The slit-width employed was $10\ \mu$. Galvanometer readings of transmission were made visually at intervals of 0.2 mm. and were later converted to densities. In addition, from one of the negatives, two traces were recorded in the same two directions as for the previous series. The rate of scanning was adjusted so as to enable the full dimension of the plate to be traversed in each direction. These two records were used for a detailed study of density variations up to a distance of 11 cm. from the edge of the mask image. Density plots derived from these are illustrated in Figs. 1A and 1B. Average values of density, D_a , have been computed for the two axes of traverse, and residual densities, ΔD , are plotted in Fig. 2, grouped according to direction of traverse, density level and emulsion.

* *Monthly Notices, R.A.S.*, 104, 33, 1944.

† *Proc. Roy. Soc., A*, 77, 56, 1906.

‡ On Newall's plate, $6\frac{1}{2}$ inches by $6\frac{1}{2}$ inches, the image diameter was 38.16 mm.

§ "Kodak" B.5 (Slow Process) plates were chosen in place of the Ilford Process plate used by Newall for the original eclipse record. The two plates have similar sensitometric characteristics. An additional pair of negatives was made on a faster emulsion, B.20 (Process Regular) plates.

Discussion of Results.—The density profiles reproduced in Figs. 1A and 1B illustrate the influence upon localised development of the geometry of the image with respect to the edges of the plate.

Adjacent to the masked area there is, for both position angles, a negative density gradient whose steepness tends to increase with decreasing distance between mask-edge and edge of plate. Its magnitude also varies with position angle, being about 20 per cent. greater for position angle 0° , *i.e.* in a direction parallel to the longer dimension of the plate. These differences will be influenced additionally by secondary factors such as the size and shape of the developing dish, and the orientation of the plate within it *, although the present investigation has not included such aspects in its purview.

At a greater distance from the mask-image, there occurs a minimum density and this is followed by a reversed gradient in which the density increases progressively as the edge of the plate is approached. These gradients, both positive and negative, may extend over distances up to 5 cm. The fact that it is possible to obtain, adjacent to the mask-image, a large-scale effect of this kind which extends radially over at least 3 cm. of background density indicates that it is an unusual manifestation of the more normal "Nachbar-effekt" whose influence is restricted to within a few millimetres of the boundary. The outer edge-effect will be influenced by any unevenness of coating thickness, or sensitivity of the emulsion. Fig. 1B serves to illustrate this. As a result of the slightly increased sensitivity of the emulsion in proximity to the edge of the plate, the density gradient is rather less steep on the left side of the mask-image than on the right where the distance between mask edge and edge of plate is greater.

Turning now to an examination of the data presented in Fig. 2, it is apparent that the density gradient resulting from the effects of non-uniform developer action is itself dependent, as regards magnitude, on the average density of the area surrounding the mask-image. Thus the curves A, B, C and D, which are plots from the density fluctuations of a pair of plates developed to moderate densities, 0.4 and 0.6 respectively, exhibit gradients which are shallow when compared with those illustrated by curves E, F, G and H, derived from measures of the plates developed to higher densities, *viz.* 0.9 and 1.6. This dependence is to be expected, since the concentration of oxidation products and soluble bromide will be greater over those areas which have been developed to the higher density levels with consequent local exhaustion of developer.

The results indicate that the maximum density gradient likely to be encountered over the range 3 to 11 mm. from the edge of the mask-image † will be of the order 0.01 per millimetre for the specific materials chosen, and under the particular conditions of this investigation. For other brands of sensitive material and for conditions other than those relevant to the experiments described here the quantitative development effect will differ from the above. It is considered, however, that the value just cited represents a rather typical set of conditions.

Application to the Photographic Photometry of the Solar Corona.—It has been demonstrated that a systematic distribution of density can occur as the result of localised differences of development of an artificial eclipse negative which has been exposed previously to a uniform background density.

Whenever estimates of intensity or brightness fluctuation are attempted through the medium of photographic photometry, density variations of this nature may give rise to significant errors in the photometric calibration. These errors will always be present if the calibration pattern impressed on plate or film differs markedly in shape, size and orientation from the geometric distribution of density in the unknown field: in general, the magnitude of the inherent error will be a function of this degree of departure. By a suitable choice of calibration conditions the magnitude of the develop-

* Newall's original paper mentions the size of plate used as $6\frac{1}{2}$ inches $\times$ $6\frac{1}{2}$ inches, but gives no details of the size of tray used for development.

† Brück's intensity measurements for the solar corona of 1905 all fall within this range.

ment effect may be so reduced as to become comparable with that of the experimental errors of reduction.

The conditions pertinent to the problem of photometering Newall's uncalibrated coronagram serve as a useful illustration of the influence of the effect. Brück's method

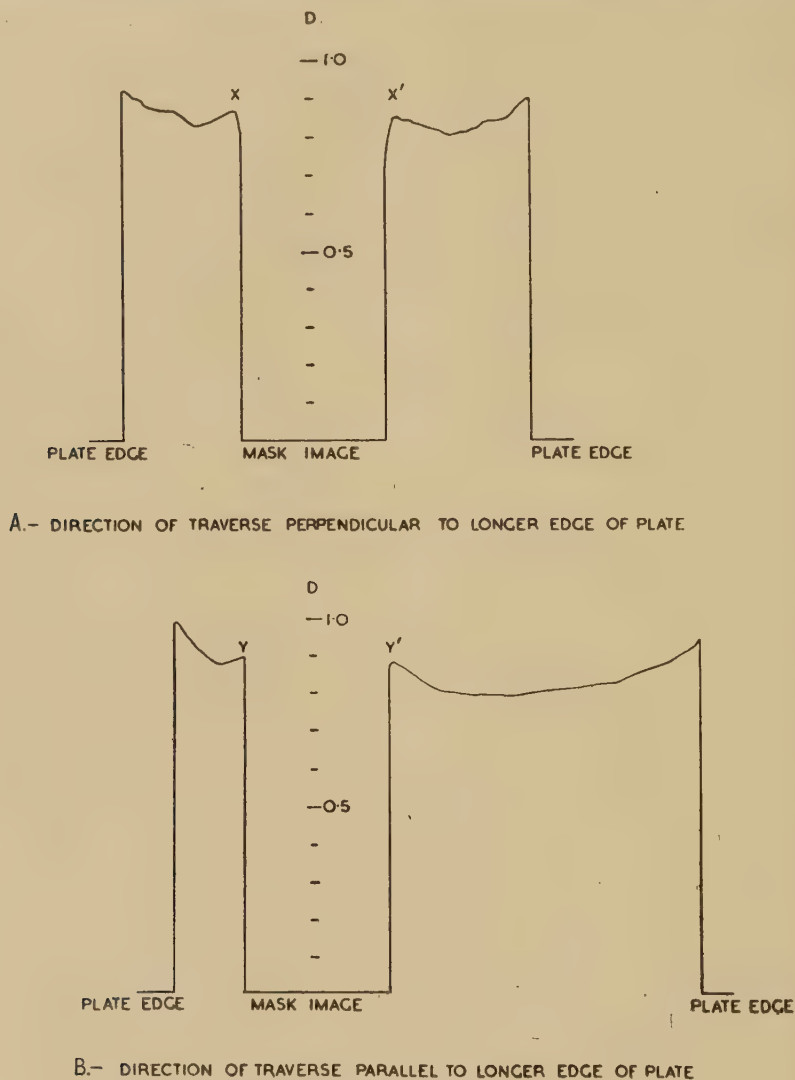


FIG. 1.—Density profiles from microphotometer tracings.

of calibration appears to have been devised so as to include automatic compensation of any photographic effects which might have influenced the original record. His calibration densities were obtained from the same photographic image as was employed afterwards for the measurement of coronal isophotes, and each density represents an average from measures at 72 position angles for points equidistant from the solar centre. Thus any radially symmetrical photographic effects would affect equally all the density measures in both calibration and unknown, and compensation would be complete. The method of calibration employed will not take care, however, of second-order effects which, as the preceding results demonstrate, may arise from any asymmetry in the radial

density gradient.* In this way, an error may be introduced into the computation of coronal intensities by assigning the contribution of development effects to the total density gradient as an effect of exposure to the coronal image.

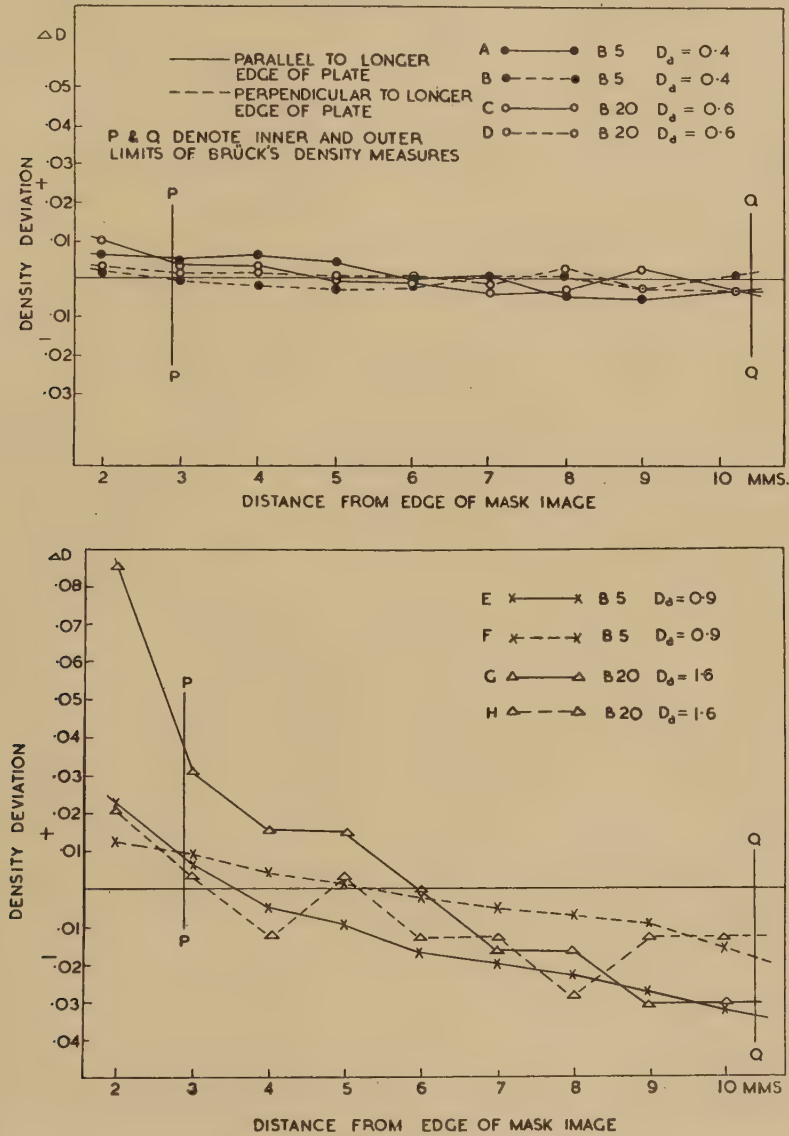


FIG. 2.—Curves illustrating the influence of developer effect at different density levels for two different emulsions.

It is of some importance, therefore, to attempt an assessment of the likely magnitude of this contribution based on the available data. Because of the steepness of the density gradient within the image of the inner corona, direct comparison with the first-order effect produced by non-uniform development is not possible. Over the range of

* In the original negative, the image of the corona was centred on a square plate: if this was developed in a square tray, preferred rocking in one direction would induce a second-order effect of the type described.

accurate measurement quoted by Brück, *i.e.* between 2.87 and 10.49 mm. from the solar limb, the mean density fell from 0.96 at 1.15 solar radii, to 0.03 at 1.55 solar radii. Using these values in conjunction with the experimental data for B.5 material a change of density with position angle of 0.01 per 90° is indicated at the upper limit of density, and zero density change at the lower limit. Expressed on a magnitude scale this will introduce an uncertainty of 0^m.01 into the observed coronal intensity variation with position angle when measured along the innermost isophote.* It is to be noted that on account of the tendency for the density gradient produced by development alone to become radially symmetrical for points very near to the limb of the Moon's image, the magnitude uncertainty which corresponds to the upper limit of density will not necessarily be the maximum possible. For example, taking an intermediate isophote corresponding to an average density of 0.4 in the original photograph (16^m.26 on the magnitude scale), the corrected magnitude values at position angles 0° and 90° are found to be 16^m.27 and 16^m.25 respectively. Thus, for this particular isophote, distant 1.2 radii from the centre of the eclipsed Sun, an uncertainty of ±0^m.01 with position angle will be contributed by the development effect. Brück's estimate of the variation imposed by the fluctuating light of the corona is ±0^m.25. Assuming therefore that an asymmetric development effect was present in the original negative, the error due to this cause when computed from the existing data will represent 4 per cent. of the total variation with position angle for the given isophote. For other isophotes, corresponding to different mean densities, the error will have values ranging from a maximum estimated to be 5 per cent. to zero. In this particular case, therefore, possible systematic errors arising from an asymmetric development effect appear to be of the same order as the accidental errors of observation.

Brück's method of calibration by utilising the unknown intensity record, and combining with it an independent observation of the intensity distribution within the inner corona must be regarded as unique in the sense that here the first-order effect is compensated for completely. Normally, the latter will be appreciably larger than any additional second-order influences. Hence, in those instances where, as is customary, an independent (external) calibration pattern has been impressed alongside the unknown exposure the first-order effect may well be significant.

Since in the majority of such cases it will be found either difficult or impossible to derive reliable corrections for both the first- and second-order effects, caution is necessary in interpreting computed intensities which are based upon uncorrected density measures.

It is a pleasure to acknowledge my indebtedness to Dr. H. A. Brück, who was kind enough to read the MS. and make a number of valuable suggestions.

*Research Laboratory, Kodak, Ltd.,
Wealdstone, Harrow, Middlesex :
1944 December 6.*

* See Fig. 2 of Brück's original paper, *Monthly Notices, R.A.S.*, 104, 33, 1944.

ERRATUM

M.N., 104, No. 4, C. S. Beals's paper:

P. 213, Legend to Fig. 4 and 9th line from the bottom, for *H γ* read *Ha*.

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*The Combination of Relativity Theory and Quantum Theory.

8vo. Dublin, 1943

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†On the Magnet, magnetick bodies also, and on the great Magnet the Earth. Translation by S. P. Thompson, with Notes.

2 vols. fol. London, 1901

Harvard College Observatory :

Mimeograms. Series I, Nos. 1-3; Series II, Nos. 1-3; Series III, Nos. 1, 2.

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A Better Sky, or name this star.

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†Physical and Chemical Constants and some Mathematical Functions. 9th edition (new impression).

8vo. London, 1943

Lick Observatory, University of California :

‡Contributions, Series II, Nos. 2, 6, 7.

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†Reports on Progress in Physics. Vol. IX.

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*Newton Tercentenary, 1642-1942.
(*British Optical Association.*)

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Norton (Arthur P.) and J. Gall Inglis :

†A Star Atlas and Reference Handbook (Epoch 1950) for students and amateurs. Ninth edition.

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No. 19. N. T. Bobrovnikoff, On systematic errors in the photometry of comets.

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- Elementary Mathematical Astronomy. Revised by Sir Harold Spencer Jones. Fifth edition. 8vo. London, 1944
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- : Report for 1943 May-1944 April. Typescript, 1944

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- *Alfred Fowler, 1868-1940 Cr. 8vo. London, 1940

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- †*Distorted equilibrium configurations of a perfect compressible fluid mass.
8vo. Washington, 1941

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- Veröffentlichung Nr. 25.
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- Practical astronomy for the Forces.
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- Apparent places of fundamental stars . . . 1945.
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- *A short table of the first five zeros of the transcendental equation
$$Y_0(x)Y_0(kx) - Y_0(kx)Y_0(x) = 0.$$

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- Vol. 1, Fasc. 1 and 2. 8vo. Lisbon, 1943

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- Technical Pamphlet No. 3.
(*W. H. van den Bos.*) 8vo. Pretoria, 1943
No. 3. W. H. van den Bos and W. S. Finsen, Handbook on the Union Observatory
Universal Sun Compass.

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- : *Table of coefficients for inverse interpolation with central differences.
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- Wave Theory. Discovery of the cause of gravitation. Book VIII.
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- Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac.
- Vol. 11, Part 1. 4to. Washington, 1943
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- Nicholas Copernicus (Quadricentennial Addresses), 1543-1943.
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- ‡*The wave-function for the negative hydrogen ion. 8vo. New York, 1942

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Considerations on the substance of the Sun. [Facsimile reprint of original, published
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NOTICE TO AUTHORS

1. *Communications*.—Papers must be communicated to the Society by a Fellow. They should be accompanied by a summary at the *beginning* of the paper. Authors are requested to submit MSS. in duplicate, when practicable.

2. *Presentation*.—Authors are allowed considerable latitude, but they are requested to follow the general style and arrangement of *Monthly Notices*. References to literature should be given in the standard form, including a date, for printing as footnotes.

3. *Notation*.—Authors should conform closely with the recommendations of Commission 3 of the International Astronomical Union (*Trans. I.A.U.*, Vol. VI, p. 345). Council has decided to adopt the I.A.U. 4-letter abbreviations for constellations where contraction is desirable (Vol. IV, p. 221).

4. *Diagrams*.—These should be drawn about twice the size required in print and prepared for direct photographic reproduction except for the lettering which should be inserted in pencil. Legends should be given in the manuscript indicating where in the text the figure should appear. Photographs are normally reproduced true to scale.

5. *Tables*.—These should be arranged so that they can be printed upright on the page.

6. *Proofs*.—Costs of alteration exceeding 5 per cent. of composition must be borne by the author. Fellows are warned that such costs have risen sharply in recent years, and it is in their own and the Society's interests to seek the maximum conciseness and simplification of symbols and equations consistent with clarity.

7. *Revised Manuscripts*.—When papers are submitted in revised form it is especially requested that they be accompanied by the original MS.

Reading of Papers at Meetings

8. If a paper is to be read at a meeting it should be received by the Assistant Secretary not later than the previous Saturday.

9. When submitting papers authors are requested to indicate whether they will be willing and able to read the paper at the next or some subsequent meeting, and approximately how long they would like to be allotted for speaking.

10. The general issue of postcards giving the programme of each meeting has been temporarily discontinued, and has been replaced by the limited circulation of abstracts of papers to be read. Announcements of organised discussions, however, will be made in advance when practicable.

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